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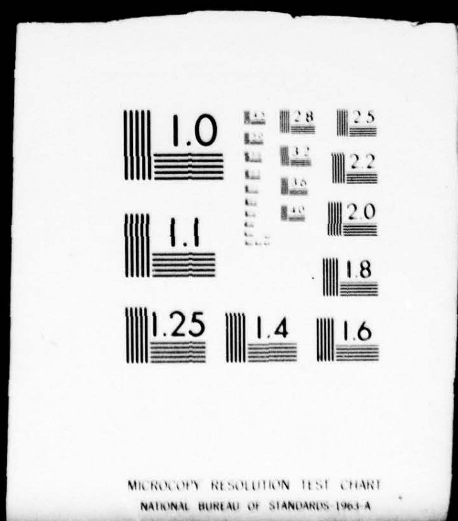

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Errata sheet for Technical Report E-153, "The Building Loads Analysis System Thermodynamics (BLAST) Program, Version 2.0: Users Manual, Volume I."

Page	
60	line 18, change ELECTRICAL to ELECTRIC
111	Table 8, line 14, delete hyphen between ONE-STAGE line 19, delete hyphen between TWO-STAGE line 20, delete hyphen between TWO-STAGE
268	line 7, change PACKAGES to PACKAGED
269	fourth line from bottom of page, change semicolon to colon after PARAMETERS
272	twelfth line from bottom of page, delete hyphen between ONE-STAGE seventh line from bottom of page, delete hyphen between TWO-STAGE sixth line from bottom of page, delete hyphen between TWO-STAGE
273	tenth line from bottom of page, delete the word FOR

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The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive set of subprograms for predicting energy consumption in buildings. There are three major subprograms: (1) the space load predicting subprogram, which computes hourly space loads in a building or zone based on user input and hourly weather data; (2) the air distribution system simulation subprogram, which uses the computed space load and user inputs describing the building air-handling system to calculate hot water or

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steam, chilled water, and electric energy demands; and (3) the central plant simulation program, which simulates boilers, chillers, onsite power generating equipment and solar energy systems and computes monthly and annual fuel and electrical power consumption and plant life cycle cost. The program is written in Control Data Corporation (CDC) FORTRAN Extended, Version 4, and can be used on CDC 6000/7000 series computers with few or no modifications. Volume I of this report provides detailed user instructions, and Volume II contains a listing of the basic BLAST program library and a BLAST example.

FOREWORD

The BLAST program was developed by the U.S. Army Construction Engineering Research Laboratory (CERL) under the sponsorship of the Air Force Engineering and Services Center (AFESC), Tyndall Air Force Base, FL, and the Department of the Army, Office of the Chief of Engineers (OCE), Washington, D.C. After its original release in December 1977, the program was extended and improved under the sponsorship of the General Services Administration, Office of Professional Services. These improvements have led to the release of BLAST Version 2.0. Hence, this Users Manual supersedes the previous BLAST Users Manual (CEEDO-TR-77-35/CERL-TR-E-119) and completely describes the information necessary to use BLAST Version 2.0. The development of this new Users Manual and a companion Input Booklet for BLAST was sponsored by AFESC, under the Investigation Engineering Program (ENE-78IE 042).

Mr. D. Warne was the General Services Administration Technical Monitor, and Mr. F. Beason was the Air Force Technical Monitor. Mr. Douglas C. Hittle was the CERL Principal Investigator. Administrative support was provided by Dr. D. J. Leverenz and Mr. R. G. Donaghy, Chief, Energy and Habitability Division, CERL. Their assistance is gratefully acknowledged.

The substantial revisions to the original BLAST program* (known as BLAST 1.2) leading to BLAST Version 2.0 were accomplished by Mr. Dale Herron, Mr. George Walton, Ms. Linda Lawrie, and Mr. John Cameron. The success of BLAST and the hoped-for success of BLAST Version 2.0 are due in large measure to their special skills and determination.

Ms. M. L. Scala, Ms. Terry James, and Ms. D. P. Mann were consulting editors on this BLAST Users Manual and on its companion document, the BLAST Input Booklet.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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*See Hittle, D. C., *BLAST, The Building Loads Analysis and System Thermodynamics Program* CEEDO-TR-77-35/CERL-TR-E-119/ADA048734 (U.S. Army Construction Engineering Research Laboratory [CERL], December 1977).

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1 INTRODUCTION

Background

The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive set of subprograms for predicting energy consumption and energy systems performance and cost in buildings. There are three major subprograms (see Figure 1):

1. The Space Load Predicting Subprogram computes hourly space loads in a building or zone based on user input and weather data.

2. The Air Distribution System Simulation Subprogram uses the computed space loads, weather data, and user inputs describing the building air-handling system to calculate hot water, steam, gas, chilled water, and electric demands.

3. The Central Plant Simulation Subprogram uses weather data, results of air distribution system simulation, and user input describing the central plant to simulate boilers, chillers, onsite power generating equipment and solar energy systems, and computes monthly and annual fuel and electrical power consumption.

Apart from its comprehensiveness, the BLAST program differs in four key respects from similar programs used in the past.

1. The BLAST program uses extremely rigorous and detailed algorithms to compute loads, simulate fan systems, and simulate boiler and chiller plants.

2. The program has its own user-oriented input language and is accompanied by a library which contains the properties of all materials, wall, roof, and floor sections listed in the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) *Handbook of Fundamentals.*[1]

3. The program execution time is brief enough to allow many alternatives to be studied economically.

4. The program is not proprietary and is, therefore, open to inspection by its users and those who rely on its results.

Scope

Volume I of this Users Manual and its companion Input Booklet (1) explain how to use the BLAST program, (2) help the user prepare BLAST program input, and (3) help the user interpret BLAST program results. Volume II contains a listing of the basic BLAST program library and a sample BLAST run.

The remaining sections of this chapter outline some of the important features and capabilities of the BLAST program and indicate the broad class of projects to which BLAST can be applied. This overview shows why given types of input data are required.

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[1] *Handbook of Fundamentals* (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1977).

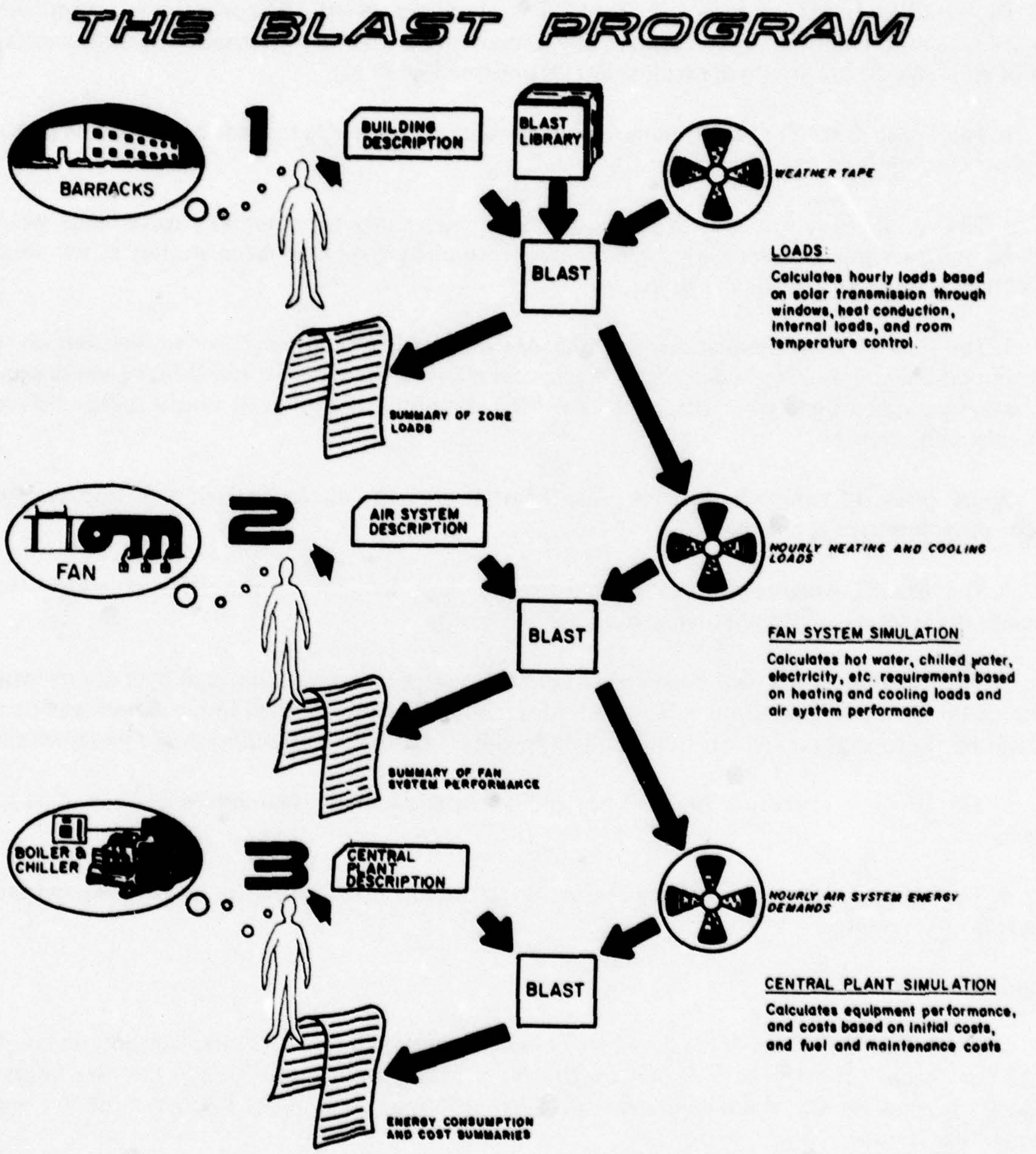


Figure 1. The BLAST program.

Chapter 2 introduces the BLAST program input language and includes a short but complete example of BLAST input.

Chapter 3 describes Lead Input in detail, including program control statements, input necessary to modify the BLAST library, and general project data (e.g., project title and location).

Chapter 4 explains how to describe buildings and zones to BLAST so zone loads can be calculated.

Chapter 5 lists the input necessary to describe fan systems used to supply heating and cooling to building zones.

Chapter 6 includes procedures used for describing central plants and for inputting parameters necessary for life-cycle costing.

Chapter 7 describes how to use BLAST to analyze building designs; the analysis is illustrated with a case study.

Chapters 3 through 6 each include an introduction, various sections on appropriate basic input data preparation topics, and a section entitled "Advanced Topics." This section can be skipped when reading the Users Manual without disrupting the manual's continuity. Advanced Topics, however, includes information which may be important to specific applications of BLAST and should be reviewed each time a new application arises.

The BLAST Input Language and Library

The BLAST program uses an unformatted, English-like input language which permits rapid input preparation. Error detection and some automatic correction make input data debugging easy. In addition, the English-like style permits rapid inspection and easy interpretation of user-supplied input.

Part of the BLAST program is the BLAST program library. The library is simply a file in which data (numbers) are stored under convenient names. It is divided into 10 subsets:

1. The Schedule Subset contains 24-hour profiles and specifications for using these profiles for each day of the week, weekends, and holidays. This subset is used when occupancy, lighting, equipment usage, and infiltration are described.

2. The Location Subset contains latitude, longitude, and time zone data for named locations.

3. The Design Day Subset contains design weather data for named design days.

4. The Control Subset contains space temperature control strategies for named control schedules.

5. The Material Subset contains the thermodynamic and optical properties of typical building materials.

6. The Wall Subset contains typical wall section descriptions composed of materials from the library's materials subset.

7. The Roof Subset contains typical roof and ceiling sections composed of materials from the materials subset.

8. The Floor Subset contains typical floor sections composed of materials from the materials subset.

9. The Door Subset contains typical door sections composed of materials from the materials subset.

10. The Window Subset contains typical window sections comprised of glass, air spaces, interior shades and drapes from the materials subset.

In addition to selected schedules and control strategies, all materials, wall, roof, and floor sections found in the 1977 ASHRAE Handbook of Fundamentals are in the BLAST library; entry names are keyed to the tables in the ASHRAE Handbook. Therefore, when preparing a building description for the BLAST program, it is not necessary to input scores of numbers. Instead, short names – which automatically select appropriate data from the library – can be used to generate the information necessary for the BLAST program calculations.

Even though the BLAST program library is comprehensive, it may not contain all the materials, schedules, wall, roof, and floor sections, and control strategies required by the user. Consequently, the BLAST program language provides the user with the capability to add, delete, modify, or temporarily define entries in any of the library's subsets, or print the contents of the entire library (alphabetically and by subset).

In addition to library data, the BLAST input language provides for the use of default equipment performance and fan system data. This permits generic systems to be investigated easily and rapidly. It also allows the user to change only those variables for which defaults are inappropriate.

The Loads Predicting Subprogram

The heart of space loads prediction is the room heat balance. For each hour simulated, BLAST performs a complete radiant, convective, and conductive heat balance for each surface of each zone described and a heat balance on the room air. This heat balance includes transmission loads, solar loads, internal heat gains, infiltration loads, and the temperature control strategy used to maintain the space temperature. Many of the important features of the loads predicting subprogram are summarized below:

1. Calculates response factors and conduction transfer functions for all zone surfaces. (This permits the careful and complete analysis of transient heat conduction through walls and of heat storage in rooms.)

2. Calculates the shaded and sunlit area for all exterior surfaces shaded by attached or detached shadow-casting surfaces (wings, overhangs, or other buildings). Also, the shading of windows caused by reveals is fully accounted for.

3. Exactly calculates the solar flux transmitted through single- and multipane windows with or without interior shades using either basic optical principles or "shading coefficients" specified by the user.

4. Accounts for the effects of both inside surface solar and infrared absorptivities and outside surface solar absorptivities.

5. Uses approximate shape factors to calculate radiant heat transfer between zone surfaces as part of the room heat balance. Also calculates the radiant interchange between exterior surfaces (i.e., walls, roofs, windows) and the earth and sky.

6. Accounts for the effects of surface roughness and hourly variations in windspeed on outside wall convective heat transfer coefficients (air film resistance).

7. Adjusts the inside surface convective heat transfer coefficient (air film resistance) for ceilings, roofs, and floors based on whether the surfaces are hotter or colder than the room air.

8. Accounts for temperature differences between a zone and an attic or crawl space by actually simulating the attic and/or crawl space.

9. Includes approximate methods for the calculation of heat flow between zones of differing temperature.

10. Allows arbitrary (user-specified) room temperature control strategies. (Different control strategies can be specified for different hours during the day and different days during the week.)

11. Appropriately allocates radiant, convective, and latent fractions of the heat from people, lights, and equipment, and allows these internal gains to be scheduled differently for each hour of the day and each day of the week.

12. Simulates the radiant and convective effects of outside air-controlled baseboard heating.

13. Accounts for the effects of windspeed, temperature, and time of day on zone infiltration.

14. Allows surfaces bounding a zone to be of arbitrary shape, three- and four-sided, and at any tilt or azimuth.

15. At the discretion of the user, allows calculated loads for each zone to be saved on tape or disk for future use in examining many alternate fan system configurations (without recalculating space loads).

16. Simulates as many as 100 zones at one time (many more than are usually required).

The Fan System Simulation Subprogram

Once zone loads are calculated, they must be translated into hot water, chilled water, and electrical demands on a central plant or utility system. This is done by using basic heat and mass balance principles in the system simulation subprogram of BLAST. The major types of air distribution systems that BLAST can analyze are:

1. Multizone and dual duct systems

2. Three-deck multizone systems

3. Single-zone fan systems with subzone reheat

4. Unit ventilators with or without heating coils

5. Two-pipe fan coil systems

6. Four-pipe fan coil systems

7. Variable volume fan systems with optional reheat or thermostatically controlled baseboard heat

8. Constant volume terminal reheat systems

9. Dual duct variable air-volume systems

10. Packaged direct-expansion systems

11. Single-zone drawthrough systems.

In addition, built-up direct-expansion cooling can be specified to serve the fan systems listed above, or chilled water can be the cooling source. Air-to-air heat recovery is also possible on most of the systems listed above. Default values are supplied for most of the pertinent fan system variables. All defaults can, however, be overridden by the user. Many combinations of mixed- and delivery-air control strategies are available for most of the air distribution systems.

The fan system simulation subprogram is unusually flexible and precise in its analysis of fan system performance. This subprogram includes the following significant features:

1. The user may adjust both the full-load efficiency and total fan pressure for supply, return, and exhaust fans as well as the part-load performance characteristics of the supply and return fans.

2. Both cold and hot decks can be controlled (a) at a fixed temperature set point, (b) at a temperature varied with outdoor air temperature, or (c) on the basis of the zone requiring the most heating or cooling.

3. The user-specified or the default-throttling range of the cold and hot deck controllers is fully accounted for.

4. Three different economy cycles can be used for most fan systems; the mixed-air temperature may be fixed or floating depending on the user specification.

5. Minimum and maximum outdoor air quantities can be scheduled for each hour of the weekday or weekend.

6. Various preheat coil configurations can be simulated.

7. Minimum and maximum outdoor air quantities can be specified. Maximum total fan volumes may be specified for variable volume systems. (The variable volume maximum and the maximum outdoor air quantity can be less than the sum of the air distributed to all zones.)

8. Humidifiers can be specified for most systems.

9. Fan, heating coil, preheat coil, cooling coil, and heat recovery operation can be scheduled on a daily and seasonal basis.

10. Users may simulate any cooling coil by specifying cooling coil design parameters consisting of typical catalog data for one coil operating point.

11. At the discretion of the user, the results of fan system simulations may be saved on tape or disk for future use in examining many alternate central plant configurations (without repeating the fan system simulations).

12. BLAST can simulate as many as 100 separate systems at one time (many more than are usually required).

The Central Plant Simulation Subprogram

Once the hot water, chilled water, and electrical demands of the building fan system are known, the central plant must be simulated to determine the building's final purchased electrical power and/or fuel consumption. The central plant subprogram of BLAST can simulate any thermodynamically feasible system consisting of any or all of the following central plant components:

1. Boilers
2. Centrifugal or reciprocating chillers
3. Absorption chillers (one and two stages)
4. Double-bundle chillers
5. Heat pumps (with or without solar assist)
6. Solar collectors and storage tank systems
7. Hot thermal storage
8. Cold thermal storage
9. Cooling towers
10. Diesel engine generators
11. Gas turbine generators
12. Steam turbine generators
13. Heat recovery from generator prime movers
14. Utility company power.

Generic data for each component model are present in BLAST, but the user may vary one or more sets of equipment performance coefficients to simulate a particular manufacturer's product.

Some of the principal features of the central plant simulation program are:

1. Accounts for the effects of ambient temperature, chilled and hot water temperature, and other operating variables on plant performance and equipment capacity.

2. Accounts for the change in equipment COP or efficiency resulting from part-load operation.

3. Allows default equipment assignment strategies to be overridden, thereby permitting the user to select the operating strategy of his/her choice.

4. Allows the user to change equipment performance parameters to permit the exact modeling of available equipment.

5. Allows detailed energy accounting which permits accurate costing of energy, particularly of purchased electricity which may have complicated block rate schedules.

6. Tabulates equipment-use statistics (hours of operation and average part-load ratio for each plant component) as well as energy consumption data, thereby permitting BLAST output to be used as the basis for equipment selection.

7. Simulates as many as 100 central plants in one run.

Life-Cycle Costing

The last step in the BLAST central plant subprogram is the calculation of life-cycle costs using present worth life-cycle costing techniques. User inputs include building construction and operating costs (excluding energy), fan system construction and maintenance costs, and user-supplied and default capital and maintenance costs for plant components. In addition, users may select appropriate fuel cost adjustment factors and discount and inflation rates.

Applications

BLAST can be applied to a wide range of projects. For example:

1. BLAST can be used for new design or retrofit projects and can simulate buildings and energy systems of almost any type and size.

2. In addition to simulating the annual performance of buildings and their energy systems, BLAST can perform peak load (design day) calculations necessary for both heating and cooling coil selection and air distribution system design.

3. BLAST can evaluate building and energy system designs to determine if they comply with design energy budgets.

4. BLAST's life-cycle costing capability can compare costs between alternate building and energy system designs.

5. BLAST can estimate annual performance, which is *essential* for the design of solar and total energy (cogeneration) systems.

6. Since repeated use of BLAST is inexpensive, it can be used to evaluate, modify, and re-evaluate alternate designs on the basis of annual energy consumption and cost. In this way, efficient designs can be separated from the inefficient; proper equipment type, size, and control can also be determined. Near-optimal designs for any new or retrofit project can be developed using this approach.

2 USING BLAST—AN OVERVIEW

Introduction

This chapter describes the steps necessary to gather data, prepare an input deck, and run BLAST.

There are four major sections to the BLAST input deck (see Figure 2):

1. Lead Input

2. Building Description

3. Fan System Description

4. Central Plant Description.

To perform a complete analysis of a building, each phase of BLAST (load calculation, system simulation, and central plant simulation) must *usually* be exercised; therefore, input data will be required for each major section. If the building is new, the data used will be based on the proposed design and will be refined based on results of BLAST simulations. For existing buildings, the majority of the input data will be based on the building as built and operated.

In this chapter, the four major sections of the BLAST input deck are used to define the data gathering steps. In actual practice, however, the data collection process can occur all at one time.

Gathering data for an existing building will probably require site visits. The BLAST input forms in the BLAST Input Booklet can be used as a checklist to help avoid the need for return visits.

Step 0. Read the Remainder of This Manual

Step 1. Obtain Access to BLAST and Obtain Weather Data

The BLAST program will usually be accessed on one of several computer service bureaus. Consequently, the first step includes contacting the representatives of the computer service bureau

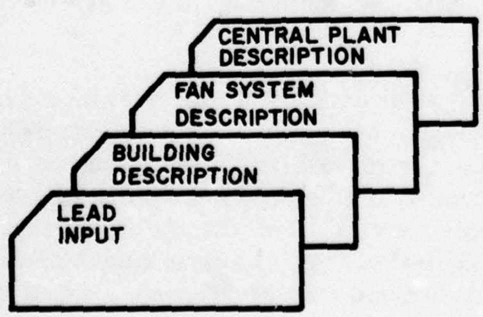


Figure 2. BLAST input deck.

preferred by the user and obtaining an account and the necessary instructions to access the BLAST program on its computers.

The complete analysis of a building using the BLAST program requires 1 year of "typical" weather data. Details of weather data tape availability and processing requirements are shown in Appendix A; however, most computer service bureaus now offer a selection of data tapes for many (usually 60) sites around the United States. Often, computer service bureaus will help the user access and process the necessary weather data. However, if the weather tape required by a user is not available, some delay can be expected; therefore, the user should check tape availabi early in the analysis process.

Step 2. Obtain a Description of the Building and Its Energy Systems

To perform accurate analyses, BLAST requires a relatively complete description of the building and its fan systems and central plant components. Consequently, it is recommended that the user collect the most detailed data possible. In particular, plans and sketches should be examined to determine wall, window, roof, and floor sections and to establish the geometry of the building. These data are required if BLAST is to fully account for the stored energy in wall, roof, and floor sections, as well as incident solar radiation and wind effects on outside walls. Since heat is also stored in partitions inside building spaces, the construction of interior partitions should also be determined.

In addition to construction details, certain usage data such as the normalized daily profiles for people, lights, equipment and infiltration are required. Normalized profiles consist of the fraction of full occupancy, lighting level, equipment usage or infiltration for each hour of the day, for each day of the week. This information is necessary because BLAST's dynamic analysis requires hour-by-hour information on the internal heat gains to a space to appropriately perform the room heat balance. Separate peak levels for lights, equipment, people, and infiltration are also required.

In addition to construction and schedule data, information on the way space temperatures are controlled must be obtained. This information is required because the heating and cooling load is directly affected by the room thermostat. For example, if a room thermostat has a dead band (e.g., no heating or cooling between 72 and 76°F [22 and 24°C]), and the room temperature remains in that region, then the heating and cooling loads are zero. This is in contrast to some other type of room temperature control which may not have a dead band but only a throttling range, e.g., full heating at 74°F (23°C) and full cooling at 76°F (24°C). With this type of room temperature control, there is always a heating or cooling load in the space. The magnitude of the heating or cooling load depends on the control strategy which becomes part of the overall heat balance performed on the room.

Certain details of the fan systems (existing or proposed) for a given building are also required; for example, the type of system and method of control are essential to proper simulation. These data are required because many control variables in the system (as well as the system type) have major effects on the system's ability to efficiently meet the heating and cooling loads. An obvious control mechanism is the on/off cycle of a fan. Clearly, if a fan system is off at night. It is not consuming energy. More subtle, but equally important considerations include the hot and cold deck control strategies (if both hot and cold decks exist), seasonal shutoff of heating or cooling or both, and the type of outdoor air control used.

Central plant (boiler/chiller plant) component data are required for the final phase of BLAST simulation. Generic data for typical boilders and chillers and other components are part of the BLAST simulation. Therefore, the minimal data required are the number and size of each of the central plant components. Other useful information would include the part- and full-load performance characteristics of the central plant components. This information can often be obtained from manufacturer's catalogs.

Step 3. Prepare Lead Input

Lead input consists of three major sections:

1. The program control section which tells BLAST which simulations to perform

2. Library modifications which include any additions to or deletions from the BLAST library

3. Project data.

The first and last of these sections can be prepared by referring to the description of Lead Input in Chapter 3. However, library modifications (also described in Chapter 3) require a careful comparison between the building and the contents of the current BLAST library. The user must compare schedules, control strategies, and wall, roof, and floor sections needed for the analysis of the building begin simulated to those available in the BLAST program library (see Volume II). For example, if a schedule or wall section needed in the building nearly or exactly matches one in the library, all the user needs to do is name the schedule or wall already listed in the library. However, if the library does not contain a wall, roof, floor, or window section which is part of the building being simulated, or if none of the schedules or control strategies in the library are appropriate for the building being simulated, library additions are required. As a minimum, design day and location data for the project will have to be added to the BLAST library.

Step 4. Prepare Building Description

Data required for the BLAST program building description comes from the building plans and information about schedules and controls collected during the data collection phase.

Details of describing a building to BLAST are given in Chapter 4. Certain building parameters that apply to all of the building (e.g., detached shading surfaces which might cast shadows over the whole building) are required, but the majority of the input is the description of individual zones in the building.

To complete the description of a zone, two data subsets are necessary. The first, and usually the most complicated, is a description of the building's geometry. The second is a description of the interior heat gains, infiltration, and space temperature control strategy (all nongeometric factors) which affect the building's heating and cooling load.

Users describe the geometry of each thermodynamic zone to the BLAST program using English-like commands that identify where each of the walls, roofs, floors, windows, and doors are located relative to an arbitrary zone origin. In this description, the construction details (i.e., materials, thickness, and thermodynamic properties) of all the layers in walls, roofs, and floors are never explicitly input: instead, the user inputs named wall, roof, and floor sections which are part of the BLAST library.

Interior heat gains and infiltration are specified by identifying the number or peak level of people, lights, equipment, and infiltration, and by identifying the schedule (the normalized profiles) which are to be used to compute the hourly value of each of these variables. Schedule details are not input during the building description phase, but are made available to BLAST by referring to the schedule name in the library. Control strategies are also input by referring to named control schedules in BLAST library.

Step 5. Prepare Fan System Description

The minimum fan system description must identify (1) the fan system type, (2) the zones in the building being served by the fan system, and (3) the air quantity delivered to each zone. Many other system parameters can also be directly controlled by the user; however, all have default values which can be used to simulate generic types of systems. For an existing building, care should be taken to change all the appropriate defaults to correspond with values of the actual building. Defaults which are frequently changed include fan efficiency, total fan pressure, hot and cold deck temperature, system schedule, outdoor air quantity, and outdoor air control method.

Step 6. Prepare a Central Plant Description

All that is required to describe a central plant to the BLAST program is (1) the fan systems being served, and (2) the appropriate size and type of the central plant equipment being used. The user may also select new values for many other system parameters if their default values are inappropriate. For example, in a solar energy system, the solar collector tilt angle, azimuth angle, and the solar system storage tank capacity are important variables which may need to be appropriately adjusted by the user.

Step 7. Perform Design Day Simulations

BLAST can simulate single days (design days) which use climatic data (i.e., daily high, daily low, wet bulb corresponding to the daily high, clearness, and windspeed) extracted from the BLAST library (DESIGN DAYS subset).

Design days are inexpensive to simulate and do not require weather data tapes. They should therefore be simulated first. This will insure that the input and output make sense. While BLAST will find (and sometimes automatically correct) user input errors, its capability is limited; it will usually find only obvious mistakes. For example, if the supply air volume to a zone is specified as 2,000 cfm (.94 m^3/s) instead of 200 cfm (.094 m^3/s), BLAST will not be aware of the error. By performing design day runs and carefully examining the results, 1-year simulations are much more likely to be error-free. Design day runs can also be used to establish both peak loads in each zone and the diversified peak load for the entire building; such information is necessary for building and system design or redesign and for equipment selection.

Step 7 can begin after Step 4, Step 5, or Step 6; that is, design day loads can be calculated for each zone and the results examined before fan systems simulation. In addition, fan system design day runs can be made before central plant simulation. In this way, air flow rates to each space can be established and proper heating and cooling coils can be selected based on the results of design day load calculations. These data can be used to define and simulate the appropriate fan systems for design days to allow peak chilled water, hot water, and electric demands to be determined, thereby permitting the preliminary selection of boilers and chillers.

Step 8. Perform 1-Year Simulations

One-year simulations should be performed after design data analyses have been completed. These simulations permit the examination of the annual performance of the building and its energy systems. (Chapter 7 describes how to use 1-year simulation results to refine the building system and central plant design.) Annual building and system performance is as important as building and system performance under peak load conditions.

It is often advisable to save intermediate results on computer tape or disk* as 1-year simulations are being done. For example, the hourly loads from the loads calculation phase can be saved and later used to test alternate fan system designs. Similarly, the results of any of the fan system simulations representing the hourly loads on the boiler/chiller plant can be saved and used in later comparisons of alternate equipment selection for the central plant.

A Simple Example

The simple input deck for the BLAST program describing the building shown in Figure 3 is shown in Figure 4. Each of the four major sections are identified (Lead Input, Building Description, Fan System Description, and Central Plant Description). The comments on the right of the input in Figure 4 indicate the type of information contained in each of the input sections. However, Figure 4 is not intended to provide complete instruction; users must read the remainder of this manual before attempting to run the BLAST program.

*Caution: Saving intermediate results on disk can be expensive; computer tapes should usually be used.

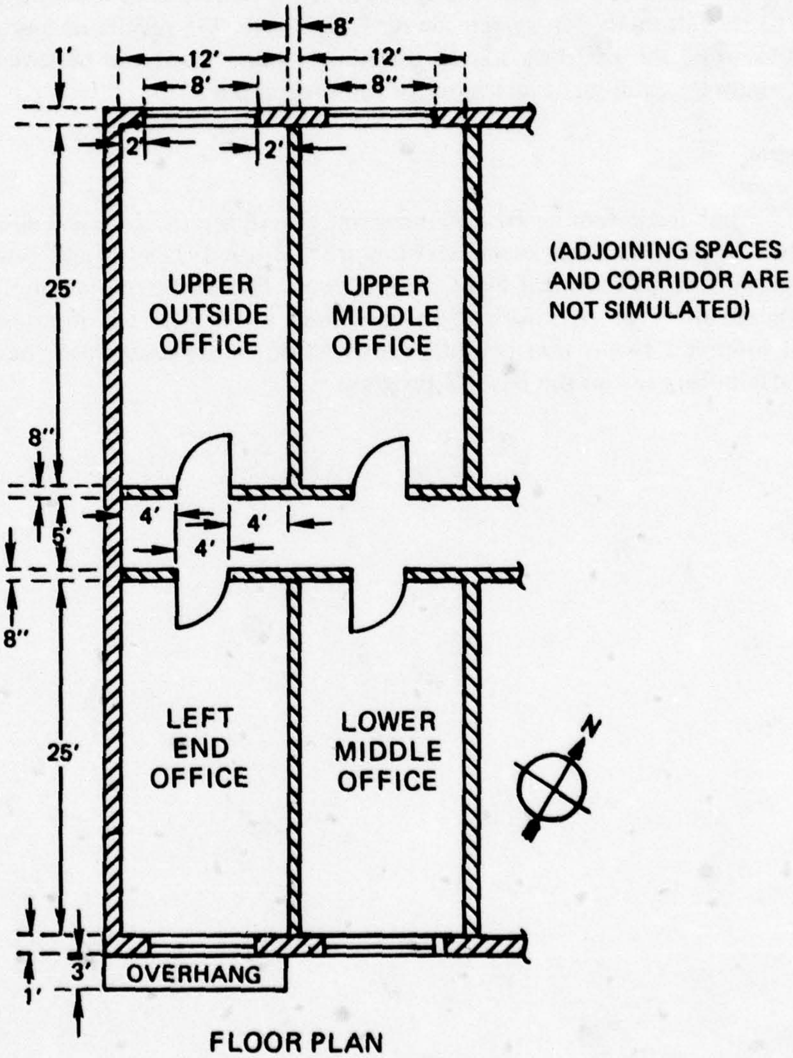


Figure 3. Specifications.

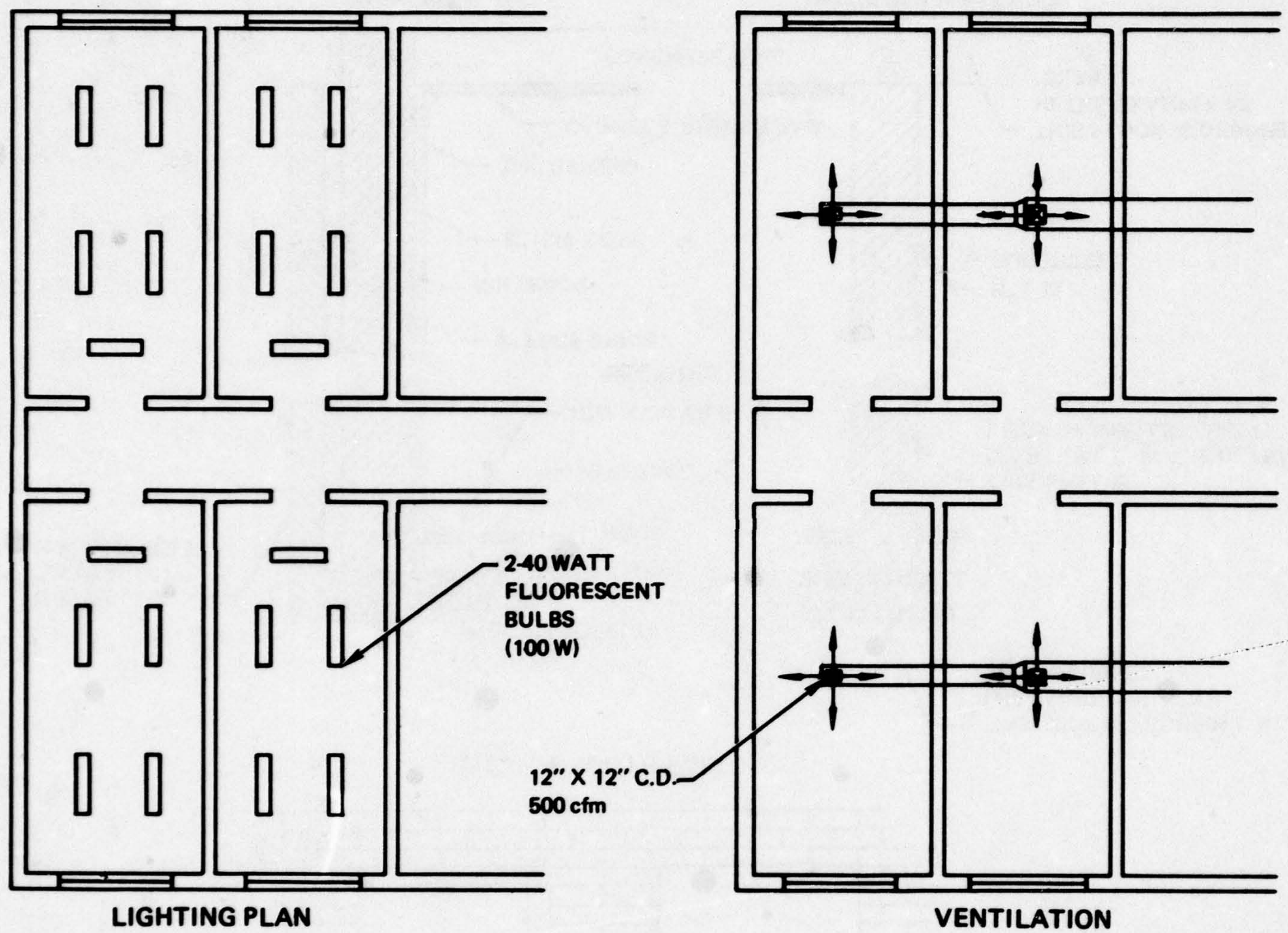


Figure 3. (cont'd)

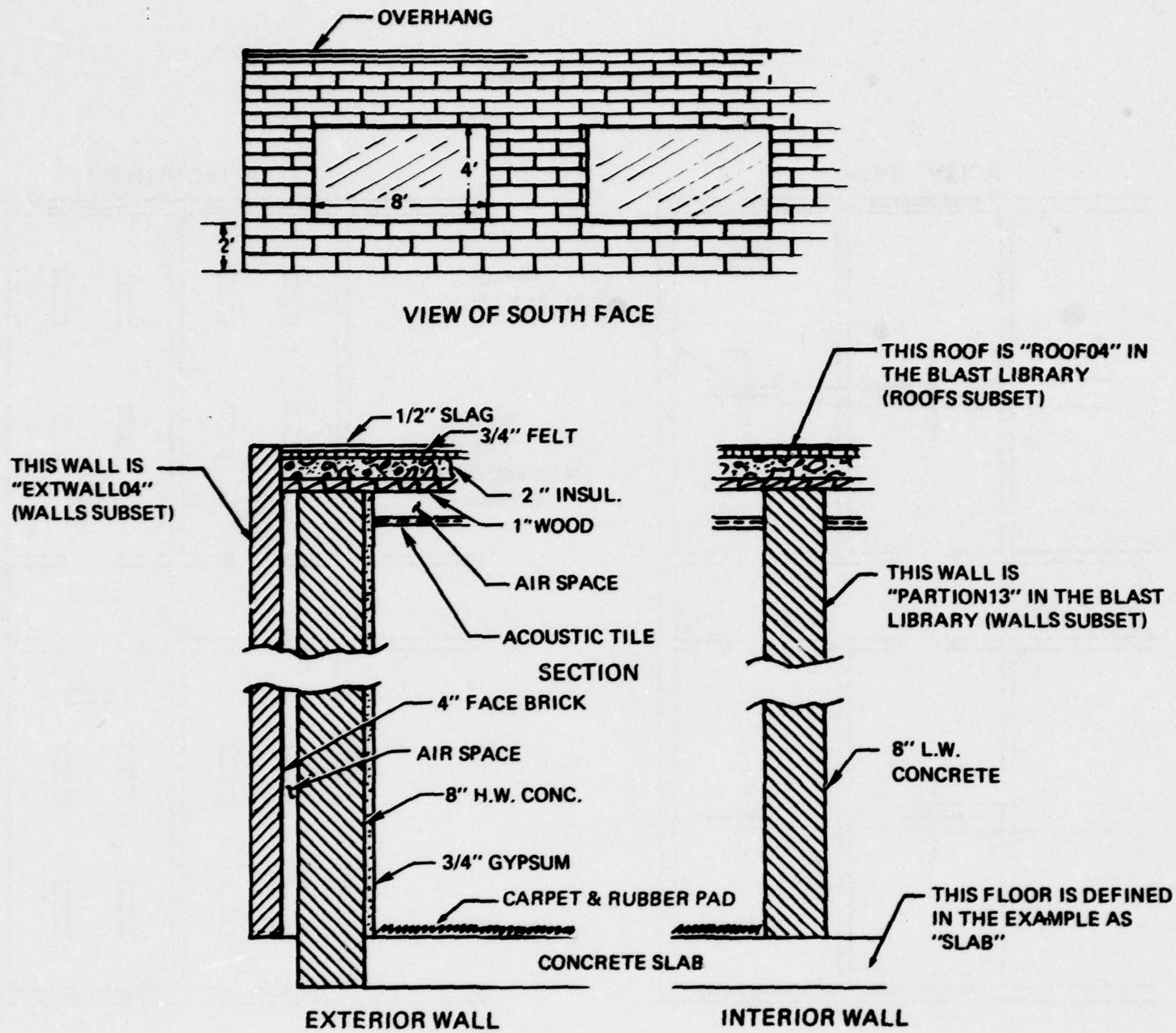


Figure 3. (cont'd)

```
BEGIN INPUT;
RUN CONTROL:
  NEW ZONES, NEW AIR SYSTEMS, CENTRAL PLANT,
  REPORTS(ZONE), UNITS(ENGLISH);
DEFINE FLOORS:
  SLAB = (DIRT 12 IN,CONCRETE - SAND AND GRAVEL 4 IN,
          FINISH FLOORING - CARPET RUBBER PAD);  END;
DEFINE LOCATION:
  COLUMBIA = (LAT=38.9,LONG=92.3,TZ=6);  END;
DEFINE DESIGN DAYS:
  COLUMBIA SUMMER = (HIGH=95,LOW=73,WB=78,DATE=21JUL,
                     PRES=405,WEEKDAY,CLEARNESS=.95),
  COLUMBIA WINTER = (HIGH=26,LOW=6,WB=25,DATE=21JAN,
                     PRES=405,WEEKEND);
  END;
PROJECT = "WORKSHOP OFFICE MODULE";
LOCATION = COLUMBIA;
DESIGN DAYS = COLUMBIA SUMMER, COLUMBIA WINTER;
WEATHER TAPE FROM 01 JAN 79 THRU 31 DEC 79;
GROUND TEMPERATURES = (40,42,48,55,62,67,70,69,63,55,48,42);
BEGIN BUILDING DESCRIPTION;
  DIMENSIONS:
    WIDTH1=12.,HEIGHT1=8., WIDTH2=8.,HEIGHT2 = 4.,WIDTH3 = 24.;
  BUILDING = "NEW OFFICE WEST WING";
  NORTH AXIS = 0;
```

This run control sequence tells BLAST what simulations to perform, specifies input and output units and asks for an optional "zone" report.

This input data adds a new floor (called "slab"), location data and two design days to the BLAST library.

Here the project title is specified and location and design day data stored in the library (added to the library by the statements above in this case) are requested. Monthly ground temperatures are specified.

LEAD INPUT (CHAPTER 3)

General Building data is given here.

BUILDING DESCRIPTION (CHAPTER 4)

Figure 4. Sample BLAST run.

```
ZONE 1 "LEFT END UNIT":
  ORIGIN:(0,0,0);
  NORTH AXIS = 0;
  EXTERIOR WALLS:
    STARTING AT (0,0,0) FACING (180)
    EXTWALL04 (WIDTH1 BY HEIGHT1)
    WITH WINDOWS OF TYPE
    SINGLE PANE HW WINDOW (WIDTH2 BY HEIGHT2)
    AT (2,2)
    WITH OVERHANG (WIDTH1 BY 3)
    AT (0, HEIGHT1),
    STARTING AT (0,25,0) FACING(270)
    EXTWALL04 (25 BY HEIGHT1);
  PARTITIONS:
    STARTING AT (WIDTH1,0,0) FACING (90)
    PARTITION18 (25 BY HEIGHT1),
    STARTING AT (WIDTH1,25,0) FACING (0)
    PARTITION18 (WIDTH1 BY HEIGHT1);
  ROOF:
    STARTING AT (0,0,HEIGHT1) FACING (180)
    ROOF04 (WIDTH1 BY 25);
  SLAB ON GRADE FLOOR:
    STARTING AT (0,25,0) FACING (180)
    SLAB (WIDTH1 BY 25);
```

The number, title, origin and north axis for the first zone are specified here.

Outside (exterior) walls are described by locating their lower left corner, specifying the direction toward which they face, naming the wall type (EXTWALL04) and giving its length and height. The BLAST program automatically extracts detailed data for each material in EXTWALL04 from the BLAST library; a window and local shading feature (overhang) are also described.

Interior partitions are specified in a manner analogous to exterior walls.

The roof and floor are similarly specified.

BUILDING DESCRIPTION (con't)

Figure 4. (cont'd)

```
PEOPLE = 2, OFFICE OCCUPANCY;
LIGHTS = 1.7, OFFICE LIGHTING;
INFILTRATION = 20., CONSTANT;
CONTROLS = NIGHT AND WEEKEND SETBACK WITH SINGLE THROTTLING RANGE.
           8 COOLING, 16 HEATING;
END ZONE;
ZONE 2 "LOWER MIDDLE UNIT":
ORIGIN: (WIDTH1,0,0);
NORTH AXIS = 0;
SAME AS ZONE 1 EXCEPT:
EXTERIOR WALLS:
  STARTING AT (0,0,0) FACING (180)
  EXTWALL04 (WIDTH1 BY HEIGHT1)
  WITH WINDOWS OF TYPE
  SINGLE PANE HW WINDOW (WIDTH2 BY HEIGHT2)
  AT (2,2);
PARTITIONS:
  STARTING AT (WIDTH1,25,0) FACING (0)
  PARTITION18 (WIDTH1 BY HEIGHT1),
  STARTING AT (WIDTH1,0,0) FACING (90)
  PARTITION18 (25 BY HEIGHT1),
  STARTING AT (0,25,0) FACING(270)
  PARTITION18 (25 BY HEIGHT1);
END ZONE;
```

Interior heat producers and infiltration are identified along with the hourly and daily profiles (stored in the library) to be used with each.

The room temperature control strategy to be simulated is given here. Details are retrieved from the library.

Zone 2 is like zone 1 except for details of geometry (and its origin). Only the differences need to be described

BUILDING DESCRIPTION (cont'd)

Figure 4. (cont'd)

```
ZONE 3 "UPPER MIDDLE UNIT":
  ORIGIN: (WIDTH3, 55, 0);
  NORTH AXIS = 180;
  SAME AS ZONE 2 EXCEPT:
  END ZONE;
ZONE 4 "UPPER OUTSIDE UNIT":
  ORIGIN:(WIDTH1,55,0);
  NORTH AXIS =180;
  SAME AS ZONE 1 EXCEPT:
  EXTERIOR WALLS:
    STARTING AT (0,0,0) FACING (180)
    EXTWALL04 (WIDTH1 BY HEIGHT1)
    WITH WINDOWS OF TYPE
    SINGLE PANE HW WINDOW (WIDTH2 BY HEIGHT2)
    AT (2,2),
    STARTING AT (WIDTH1,0,0) FACING (90)
    EXTWALL04 (25 BY HEIGHT1);
  PARTITIONS:
    STARTING AT (0,25,0) FACING (270)
    PARTITION18 (25 BY HEIGHT1),
    STARTING AT (WIDTH1,25,0) FACING (0)
    PARTITION18 (WIDTH1 BY HEIGHT1);
  END ZONE;
END BUILDING DESCRIPTION;
```

Zone 2 is simply turned around and relocated to produce zone 3.

This zone is described in a fashion similar to zone 2 above.

BUILDING DESCRIPTION (cont'd)

Figure 4. (cont'd)

```
BEGIN FAN SYSTEM DESCRIPTION;
  MULTIZONE SYSTEM 72 "MAIN FAN SYSTEM" SERVING ZONES 1,2,3,4;
    FOR ZONE 1;
      SUPPLY AIR VOLUME=500.;
      END;
    FOR ZONE 2;
      SUPPLY AIR VOLUME=500.;
      END;
    FOR ZONE 3;
      SUPPLY AIR VOLUME=500.;
      END;
    FOR ZONE 4;
      SUPPLY AIR VOLUME=500.;
      END;
    END SYSTEM;
  END FAN SYSTEM DESCRIPTION;
BEGIN CENTRAL PLANT DESCRIPTION;
  PLANT 4 "BASIC BOILER & CHILLER" SERVING SYSTEM 72;
    EQUIPMENT SELECTION;
      1 CHILLER OF SIZE 160.
      1 BOILER OF SIZE 160;
      END;
  END PLANT;
  END CENTRAL PLANT DESCRIPTION;
END INPUT;
```

This brief fan system input shows the minimum required: i.e., system number, system type, zones served, and supply air volume for each zone. In the absence of any other user input, a standard set of defaults are used to define the many performance parameters of the fan system (i.e., hot and cold deck temperature, coil capacities, fan efficiences).

FAN SYSTEM DESCRIPTION (Chapter 6)

A boiler/chiller plant is described here by simply indicating the number, type, and size of each plant component. Other variables will take on default values (i.e., temperautre, pressure, flows) unless overridden by other user input.

CENTRAL PLANT DESCRIPTION (Chapter 6)

Figure 4. (cont'd)

3 LEAD INPUT

Introduction

The BLAST input deck begins with the phrase

BEGIN INPUT;

and ends with

END INPUT;

These phrases, like all others in the BLAST language, can be in any column on the punched card or between columns 1 and 80 inclusively when input is entered via an interactive terminal. At least one space separates words (more than one is perfectly acceptable) and punctuation (i.e., semicolons, colons, commas, equal signs, and parentheses) is *required* as shown. Spaces to the right or left of punctuation are optional. When numbers are required, they may appear with or without decimal points; the exceptions are numbers which can only be integers. These numbers should be input without decimal points (i.e., time zone numbers, time of day, day of the month, and numbers identifying zones or systems). Very little of the BLAST input is order dependent. The amount of information on each card or line, the indentation scheme, or how blank lines or cards are used is at the complete discretion of the user. Any formatting style which makes the input readable is satisfactory. The BLAST Input Booklet[2] contains input forms which use a convenient formatting style. The use of these forms may reduce input and keypunching errors.

Any time two asterisks (**) appear together on a card or line, the remainder of that card or line is assumed to be a comment and is repeated when BLAST prints the input.

The first of the four major BLAST input blocks is Lead Input. Lead Input consists of three major sets of data:

Program control

Library modifications

Project parameters

The program control command RUN CONTROL tells BLAST what to do with the input data and what simulations to perform.

Library modifications follow RUN CONTROL and are statements defining, redefining, deleting, or temporarily defining entries in any of the 10 BLAST library subsets.

Project parameters are a collection of project data input, including project title, location, name of design days, ground temperatures, and the period of simulation desired if a weather tape is being used (the start and end date of the simulation).

---

[2]Sowell, E., *BLAST, The Building Loads Analysis and Systems Thermodynamics Program Input Booklet*, Technical Report E-154 (U.S. Army Construction Engineering Research Laboratory [CERL], June 1979).

Program Control

If a RUN CONTROL statement is used, it must appear immediately following BEGIN INPUT;. The following example illustrates each of the six parameters of a RUN CONTROL statement.

May be omitted or ADD ZONES, or REPLACE ZONES, may be used instead

May be omitted or ADD AIR SYSTEMS, or REPLACE AIR SYSTEMS, may be used instead

May be omitted

Required punctuation

```
RUN CONTROL:  NEW ZONES, NEW AIR SYSTEMS, CENTRAL PLANT,
              REPORTS (ZONE, SYSTEM), UNITS (ENGLISH), PRINT LIBRARY;
```

May be omitted or any of these report names may also be included within the parentheses: WALLS, ZONE, SHADE, CONTINUOUS, COIL LOADS, SYSTEM, EQUIPMENT PARAMETERS

If omitted, input and output are ENGLISH. Other options are: UNITS (METRIC) UNITS (IN=METRIC, OUT=ENGLISH), UNITS (IN=ENGLISH, OUT=METRIC)

Causes printing of library (may be omitted)

Required terminator for RUN CONTROL sequence.

The parameters can be in any order. Each is separated from the next with a *comma*. A semicolon follows the last parameter (replacing the comma) and terminates the RUN CONTROL sequence. Each of the parameters is described below.

Users may select any one of the three phrases listed below to tell BLAST what type of zone load calculations to perform. If none of the following phrases are used, no loads will be calculated.

NEW ZONES

ADD ZONES

REPLACE ZONES

NEW ZONES tells BLAST to calculate loads for the zones described in the building description input block. All previous load calculations, if any, are disregarded.

ADD ZONES tells BLAST that (1) the user has saved previously calculated loads data for one or more zones and now wishes to add calculated loads for new zones to the same load data file, (2) the zones to be added, and only these zones, are described in the building description input block, (3) since each zone has a zone number assigned by the user, the added zones must be assigned numbers different from any numbers previously used*, and (4) loads are to be calculated for the described zones and the hourly results added to the loads data file.

---

*If previously assigned zone numbers are used, **BLAST** will stop after processing input.

REPLACE ZONES tells BLAST that (1) the user has saved previously calculated loads data for one or more zones, but one or more of these zones have changed or were simulated incorrectly, (2) only zones for which loads are to be recalculated are described in the building description input block, (3) the replaced zones *must* have the same zone number as one of the previously simulated zones*, and (4) loads are to be recalculated for the described zones and the hourly results are to replace previously calculated results on the loads data file. (Hourly results for previously calculated zone loads for zones not described in the building description block are not changed.)

The user may select one of a similar set of three phrases to control fan system simulation:

NEW AIR SYSTEMS

ADD AIR SYSTEMS

REPLACE AIR SYSTEMS

If none of these phrases is selected, no fan system simulation will occur. Each phrase serves a function analogous to the **NEW**, **ADD** and **REPLACE ZONES** commands. **ADD AIR SYSTEMS** and **REPLACE AIR SYSTEMS**, however, modify previously saved fan system simulation results and require appropriate system descriptions in the fan system description input data block. Like zones, each fan system is assigned a number by the user. Hence, only new systems with new numbers can be described when **ADD AIR SYSTEM** is used. Only systems whose numbers duplicate previously simulated systems can be described when **REPLACE AIR SYSTEMS** is used.

Any fan system simulation requires that zone load data be available either as a result of zone load calculations performed during the same BLAST run or by "attaching" saved results from a previous load calculation. (See Appendix B for details.)

The **CENTRAL PLANT** parameter of **RUN CONTROL** causes BLAST to simulate a user-described central plant using either the results of fan system simulations performed during the same BLAST run or saved results from a previous fan system simulation. If **CENTRAL PLANT** is omitted, no central plant simulation is performed and life-cycle costs are not calculated.

The **REPORTS** parameter of **RUN CONTROL** allows the user to ask for reports other than those which are automatically printed during any BLAST run. Optional reports are described in the Advanced Topics sections of Chapters 4, 5, and 6.

The **UNITS** parameter of **RUN CONTROL** indicates whether input and output are to be in English or metric units. If this parameter is omitted, BLAST will expect English units as input and will print reports in English units. Table 1 indicates English and metric units for various quantities which may be input to BLAST**.

The **PRINT LIBRARY** parameter of **RUN CONTROL** causes the BLAST library to be printed alphabetically by subset. If this parameter is omitted, the library will not be printed.

---

*If a replaced zone is not assigned the same zone number as a previously simulated zone, BLAST will stop after processing input.

**Throughout the text, SI units or derived SI units are shown in parentheses. Users *may not* mix units in preparing BLAST input, but must select the English *or* Metric systems shown in Table 1.

Table 1
English and SI Units to Be Used for Describing Input Variables

Variable Type	English Unit	Metric Unit
Conductivity	Btus per hour-foot-°F (Btu/hr-ft-F)	watts per meter-°K (W/[m-K])
Density	lb mass per cubic foot (lbm/cu ft)	kilogram per cubic meter (kg/m^3)
Flow Rate	cubic feet per minute ([cu ft/min] or CFM)**	cubic meters per second (m^3/s)
Heat Content (of Fuels)	Btus per pound mass (Btu/lbm)	kilojoules per kilogram (kj/kg)
Heat Release Rate or Equipment Capacity++	thousands of Btus/hour (kBtu/hr)	kilowatt (kW)
Length	foot (ft)	meter (m)
Mass	pounds mass (lbm)	kilograms (kg)
Pressure*	inches of water (in. H_2O) (1 PSI = 27.71 in. of water) (1 atmosphere ≅ 407 in. H_2O)	Newtons per square meter or Pascals (Pa)
R-value	hour-square foot-°F per Btu (hr-sq ft-°F/Btu)	square meters-°K per watt (m^2-°K/W)
Specific Heat	Btu per pound mass-°F (Btu/[lbm-°F])	kilojoules per kilogram-°K (kj/kg-°K)
Speed	feet/minute (ft/min)***	meters/second (m/s)
Temperature+	°F (°F)	°C (°C)

*The unit "inches of water" is convenient for fan pressure specification even if somewhat inconvenient for barometric pressure.

**1 cu ft = 7.48 gallons.

***1 mph = 88 ft/min.

+Note: Centigrade is not a true SI scale (°K is strictly more correct) but is a derived SI unit and much more convenient as an input variable unit. Some equipment performance parameters (see Appendix G) must be developed using absolute temperature (°K or °R). The user should carefully note these parameters.

++Note that kilowatt and kBtu/hr are used for convenience in some cases instead of watts and Btu/hr. Also, in most cases, metric output energy units will be kilowatt-hours (kWh) rather than joules, because most users are more familiar with the kWh unit.

If the entire RUN CONTROL sequence is omitted, no simulation will be performed; however, BLAST *will* process the remaining input and check for and identify any syntax errors. If the RUN CONTROL sequence is used, at least one of the six RUN CONTROL parameters must be specified.

Library Modifications

Commands

Since the BLAST library contains data stored under names, the user need only input the library name in order to make the data available to BLAST. For example, EXTWALL04, a named wall

section in the BLAST library, was used in the example shown in Chapter 2. By using this name, data on each of the materials which make up the wall (in this case, four materials) are automatically extracted from the library. These data may typically include a material name, its thickness, density, conductivity, specific heat, surface roughness, and solar and infrared absorptivity. Thus, using the library name EXTWALL04 is equivalent to inputting more than 30 individual pieces of data.

The BLAST library is divided into 10 subsets, each containing different types of data:

SCHEDULE – contains hourly and daily profiles used to schedule lighting, equipment, occupancy, and infiltration

LOCATION – contains latitude, longitude, and time zone data used to perform design day simulations

DESIGN DAYS – contains selected weather data for design or peak conditions

CONTROLS – contains hourly and daily zone temperature control strategies

MATERIALS – contains thermodynamic and optical properties of common construction materials (used to define walls, roofs, floors, windows, and doors)

WALLS – contains wall and partition sections

ROOFS – contains roof and ceiling sections

FLOORS – contains interior and exterior floor sections

DOORS – contains door sections

WINDOWS – contains window sections

The user can change the library using any of four commands:

DEFINE

REDEFINE

TEMPORARY

DELETE

The DEFINE command adds data stored under a new name to the library.

The REDEFINE command replaces old data with new data stored under an existing name in the library.

The TEMPORARY command defines an entry with either a new or old name for the duration of the current simulation only.

The DELETE command erases both name and data from the library.

For each library subset except **SCHEDULES** and **CONTROLS**, the commands to perform library modifications take the general form shown below.

Can be REDEFINE or TEMPORARY

Library subset name,
Typical required punctuation

```
DEFINE FLOORS:

FLOOR38 = (E5 - ACOUSTIC TILE, E4 - CEILING AIR SPACE,

     C12 - 2 IN HW CONCRETE),
```

Data

Names under which data are stored in the library

```
FLOOR37 = (B11 - 3 IN WOOD),

END FLOORS;
```

Ends this library modification (END; is equivalent)

Walls, Roofs, Floors, Windows, and Doors

For walls, roofs, floors, windows, and doors, data within the parentheses are the names of materials from the materials subset of the library. They are given in order from outside to inside and are separated by commas (no comma after the last specified layer). Up to ten layers may be specified. In **FLOOR38** above, for example, the outside layer is the acoustic tile below the floor, the next layer is the air space above the tile, and the inside layer is the concrete floor deck. **CEILING38** in the **ROOFS** subset has the materials in the opposite order (i.e., concrete floor deck, air space, acoustic tile). Outside and inside air film resistances are *never* given as part of a wall, roof, floor, window, or door definition since they are adjusted hourly during the BLAST simulation.

Transparent materials in the materials library subset are identified as **AIR**, **SHADE**, or **GLASS** layers. When defining, redefining, or temporarily defining windows, only those materials identified as **AIR**, **SHADE**, or **GLASS** should be used; all other materials are assumed to be opaque.

Materials

Materials are defined in a format similar to that used for walls, roofs, floors, windows, and doors. For example:

```
DEFINE MATERIALS:

  E5 - ACOUSTIC TILE = (L = .0625, K = .035, D = 30, CP = .20,
                        ABS = .32, MEDIUM SMOOTH),

  E4 - CEILING AIR SPACE = (R = 1.0, AIR),

  C12 - 2 IN HW CONCRETE = (L = .167, K = 1.0, D = 140, CP = .2,
                            ABS = .65, MEDIUM ROUGH),

  END MATERIALS;
```

The data set which defines materials lists the thermodynamic and optical properties of the material being defined. The general sequence for defining materials is as follows:*

```
DEFINE MATERIALS:

  usname = (L = usn1, K = usn2, CP = usn3, D = usn4, ABS = usn5,
            TABS = usn6, R = usn7, TRANS = usn8, IR = usn9,
            FILMTRANS = usn10, REF = usn11, SC = usn12
            roughness, asg);
     •
     •  other materials
     •
END MATERIALS;
```

where,

	L	=	the thickness in ft (or m)
	K	=	conductivity in Btu/hr-ft-°F (or W/m °K)
	CP	=	specific heat in Btu/lbm-°F (or kJ/kg °K)
	D	=	density lbm/ft^3 (or kg/m^3)
	ABS	=	absorptivity in the solar spectrum (if not specified, the default is 0.75) See Appendix C for typical construction material absorptivity.

*In the example, usname indicates user must specify a name; usn indicates user must specify a number.

TABS = absorptivity to thermal radiation (if not specified, the default is 0.9)

R = overall R value of the material in hr-sq ft-°F/Btu (m^2-°K/W)

TRANS = the transmittance of glass or shades (for glass with reflective films or coatings, this is the transmissivity of the bare glass)

FILMTRANS = the transmittance of the same glass with its reflective film (specified only for glass with reflective films or coatings)

IR = index of refraction (if not specified, the default is 1.52 for glass and 1.0 for air)

REF = the reflectance of interior shading devices

SC = shading coefficient

roughness = one of the following phrases indicating the surface roughness*:

VERY ROUGH	–	Stucco, built-up roof with stone, wood shingles
ROUGH	–	Brick, plaster, concrete block
MEDIUM ROUGH	–	Concrete, asphalt, shingles
MEDIUM SMOOTH	–	Clear pine
SMOOTH	–	Smooth plaster or metal
VERY SMOOTH	–	Glass or smooth painted surfaces

asg = the air, shade, or glass indicator used to specify materials which may later form parts of a window section (must be AIR for air layers, SHADE for interior shades [i.e., drapes, venetian blinds], or GLASS for glass layers). These indicators are used in establishing the optical properties of window construction.

It is never necessary to specify all the above parameters when defining materials. For example, the only parameters required to define opaque walls, roofs, or floor materials are L, CP, D, K, ABS, and roughness. In addition, ABS and roughness need not be specified if the defaults are acceptable for the specified materials. TABS defaults to 0.9, a value typical of most common

*The default for roughness is ROUGH, unless the material is glass, in which case the default is VERY SMOOTH. Roughness is important for materials forming the outside layer of an exterior wall.

materials. Alternatively, R can be used in place of the L, CP, D, and K (if R is not specified, L, CP, D *and* K [all four] must be specified). Using R is appropriate for lightweight materials or for materials that are highly conductive compared to their total ability to store heat. For example, the only parameters required to define glass are R, TRANS, and the word GLASS. Roughness will default to VERY SMOOTH, and IR will default to 1.52. If the glass is unusually thick, L, CP, D, and K may be specified to account for its heat storage effect.

For air spaces, the R value and the word AIR are the only requirements. IR will default to 1.0, based on the occurrence of the word AIR; since the material is very lightweight and can store little heat, the R value alone suffices to describe it thermodynamically (for AIR layers, TRANS and ABS are *not* used by BLAST, even if specified).

For interior shades used in defining window sections, TRANS, REF, and the word SHADE are the only requirements since, in BLAST, a SHADE only affects the optical properties of a window (if insulating drapes or other interior shade affect the conductive properties of the window section, additional resistance [a larger R] should be specified for the air layer between the glass and the interior shade).

A shading coefficient, SC, should only be specified for GLASS materials for which data on TRANS or IR are not available (i.e., glass block or frosted glass). GLASS materials for which SC is specified may be used *only* as the outside layer when defining windows. SC becomes the shading coefficient for the entire window section and optical properties of other layers (if any) are ignored.

Location

Locations can be defined in a fashion similar to other library entries (data in this sample modification are the latitude, longitude, and time zone of Boise, ID):

```
DEFINE LOCATION:

    BOISE = (LAT = 43.57, LONG = 116.22, TZ = 7),

END LOCATION;
```

Data for a particular location entered into the library, as shown above, are later used to allow the sun's position to be accurately determined when design day simulations are performed. However, when a weather tape is made available for 1-year simulations, the latitude, longitude, and time zone are taken from the weather data tape. The location specified by the user is ignored. Appendix D contains a time zone map and latitude and longitude data for many U.S. cities.

Design Days

Design days, used to calculate peak heating and cooling loads, are defined in the same way as library modifications for other library subsets. The following is a sample design day definition.

```
DEFINE DESIGN DAYS:

    BOISE WINTER = (HIGH = 26, LOW = 6, WB = 25, DATE = 21JAN, PRES = 405,
                    WS = 660, DIR = 245, CLEARNESS = .9, WEEKDAY, SNOW),

    BOISE SUMMER = (HIGH = 88, LOW = 65, WB = 73, DATE = 2AUG, PRES = 410,
                    WS = 352, DIR = 230, CLEARNESS = 1.05, WEEKDAY),

END DESIGN DAYS;
```

The general syntax for defining design days is

```
DEFINE DESIGN DAYS:

    usname = (HIGH = usn1, LOW = usn2, WB = usn3, DATE = usdate,
              PRES = usn4, WS = usn5, DIR = usn6, CLEARNESS = usn7,
              usname1, usname2),

END DESIGN DAYS;
```

where:

usname	=	an arbitrary name for the design day
HIGH	=	the day's high dry bulb temperature, °F (or °C)
LOW	=	the day's low dry bulb temperature, °F (or °C)
WB	=	the wet bulb temperature corresponding to the daily high, °F (or °C)
DATE	=	the day and month for the design day with a one or two number day and a month abbreviated to three characters
PRES	=	the barometric pressure in inches of water (or Pascals)

WS	=	the wind speed for the day in ft/min (or m/s)
DIR	=	the wind direction (from 0 to 360° – compass notation)
CLEARNESS	=	the clearness number for the site on the design day*
usname1	=	one of **WEEKDAY**, **WEEKEND**, or **HOLIDAY** (Schedules and control strategies for Monday are used if **WEEKDAY** is selected, for Sunday if **WEEKEND** is selected, and for holidays if **HOLIDAY** is selected)
usname2	=	one of **RAIN** or **SNOW** or no entry (if **RAIN** is specified, exterior surface temperatures will take on the value of the outdoor wet bulb temperature; if **SNOW** is specified, the ground reflectivity will be adjusted upward when the design day calculations are performed).

For any design day data not specified by the user when defining a design day, the unspecified parameters take on the defaults shown below:

```
      HIGH = 95
       LOW = 52
        WB = 78
      DATE = 21 JUL
      PRES = 4Ø5
        WS = 66Ø
       DIR = 27Ø
 CLEARNESS = 1.Ø
   WEEKDAY.
```

The basic library does not contain design day data. Hence, users will usually have to define one or more design days for their location.

---

*See *ASHRAE Handbook of Fundamentals*, p. 26.9.

DELETE *Command*

The **DELETE** command differs only slightly from the **DEFINE**, **REDEFINE**, and **TEMPORARY** commands. The difference is that data specified when adding or changing an entry in any of the above library subsets are *not* specified when deleting an entry. For example:

Can be MATERIALS, WALLS, ROOFS, DOORS, WINDOWS, LOCATION or DESIGN DAYS

Required punctuation

```
DELETE FLOORS:
    FLOOR38,
    FLOOR37,
END FLOORS;
```

Names of data to be deleted from the specified library subset

Required punctuation

Ends this DELETE sequence. END; is equivalent.

General Schedule

The definition of schedules (and room temperature control strategies) requires a somewhat different format than library modifications because considerably more data are specified. Each schedule (or control strategy) is separately defined; i.e., **DEFINE**, **REDEFINE**, or **TEMPORARY** commands are issued for each schedule, followed by the appropriate **END** command.

Schedules define 24-hour profiles for each day of the week and for holidays. This allows lighting, occupancy, equipment, and infiltration profiles for the zones to be described later. The following is a sample schedule definition:

Can be REDEFINE or TEMPORARY

Library subset is SCHEDULE

Name under which data are stored in library

```
DEFINE SCHEDULE (OFFICE OCCUPANCY):
```

Weekly period

Hourly Period and profile value

Values for individual hours (6 to 7 and 7 to 8 . . . in this example)

```
    MONDAY THRU FRIDAY = ( 18 TO Ø6-Ø, .1, .5, 1.Ø, 1.Ø, 1.Ø, 1.Ø,
                           .5, 1.Ø, 1.Ø, 1.Ø, .5, .1 ) ,
    SATURDAY THRU SUNDAY = ( ØØ TO 24-Ø.Ø ) ,
    HOLIDAY = SUNDAY ;
```

Typical required punctuation

One daily profile can be equated to another, previously specified profile

```
END SCHEDULE;
```

END; is equivalent

Schedules can also be defined in the following way (each interval during the day is explicitly stated, i.e., 06 TO 07-.2 rather than . . . . , .2, . . .):

```
DEFINE SCHEDULE ( OFFICE LIGHTING ) :
                                        Typical required punctuation
     MONDAY THRU FRIDAY = ( 18 TO 06-.05, 06 TO 07-.2, 07 TO 17-1.0,
                             17 to 18-0.5 ) ,

     SATURDAY THRU SUNDAY = ( 00 TO 24-.05 ) ,

     HOLIDAY = SUNDAY;

END SCHEDULE;
```

In each of the samples above, the schedule definition begins with the phrase **DEFINE SCHEDULE** (usname):. Following this initial statement, 24-hour profiles are defined for each day of the week. In the examples, the profiles are the same for Monday, Tuesday, Wednesday, Thursday, and Friday; hence, **MONDAY THRU FRIDAY** was used to define the weekday profile. Similarly, the weekend (**SATURDAY THRU SUNDAY**) has one profile. Holidays have the same profile as the weekend. However, if separate profiles are to be specified for each day, the input would be:

```
DEFINE SCHEDULE (schedule name):

     MONDAY = (24-hour profile data),

     TUESDAY = (24-hour profile data),
     •
     •
     •
     HOLIDAY = (24-hour profile data);

END SCHEDULE;
```

Note how **THRU** and **TO** are spelled and used in the daily profiles. These use conventions follow normal English idiom; i.e., "I work on Monday thru Friday from 8 to 5." The days of the week can be specified in any order. For example, **FRIDAY THRU MONDAY** will include Friday, Saturday, Sunday, and Monday. **TUESDAY THRU MONDAY** will include the entire week. Holidays must be separately specified. Any day of the week (or holiday) can be equated to any other day whose schedule has already been defined.

Control Strategies

The definition of control strategies requires first that control profiles be specified, then that each profile be appropriately assigned to a time of day for each day of the week. The seasonal availability of heating and cooling may also be specified. For example:

Can be REDEFINE or TEMPORARY

Library subset is CONTROLS

Typical required punctuation

```
DEFINE CONTROLS ( NIGHT AND WEEKEND SETBACK
                  WITH DUAL THROTTLING RANGES ) :
```

Name under which data are stored in library

Profiles are defined first

```
    PROFILES :
```

Typical required punctuation

```
      HEATANDCOOL = ( 1.Ø AT 67, Ø.Ø AT 69, Ø.Ø AT 77, -1.Ø AT 79 ),
```

Profile names, only one word no spaces

Profile descriptions

```
      SETBACK = ( 1.Ø AT 6Ø, Ø.Ø AT 62 ) ;
```

Profiles are assigned for each hour of each day

Required punctuation

```
    SCHEDULES :
```

Typical required punctuation

```
      MONDAY THRU FRIDAY = ( Ø7 to 17-HEATANDCOOL , 17 TO Ø7-SETBACK ),
```

Names of profiles defined above (OFF can also be used to signify no heating or cooling)

```
      SATURDAY THRU SUNDAY = ( ØØ TO 24-SETBACK ) ,
```

Commas separate daily schedules; a semicolon follows the last daily schedule

```
      HOLIDAY = SUNDAY ;
```

As with SCHEDULES, any day of the week or HOLIDAY can be equated to any previously defined day.

```
    HEATING ON FROM Ø1 JAN THRU 31 DEC;
    COOLING ON FROM Ø1 JAN THRU 31 DEC;
```

User supplied dates

Specifies seasonal availability of heating and cooling. If omitted, year around availability is the default (this example is the default).

```
END CONTROLS;
```

END; is equivalent

The sample control definition above defines the control profiles shown in Figure 5.

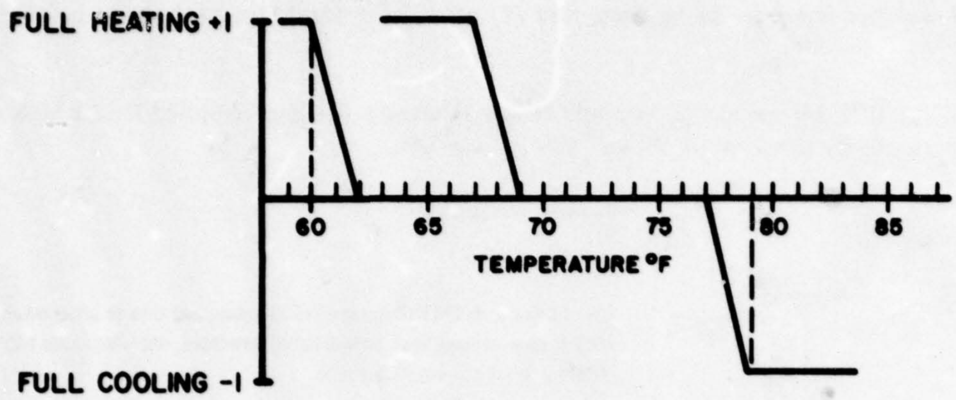


Figure 5. Control profiles for sample.

Control profiles are defined by specifying the fraction of full heating or cooling available AT a specified room temperature. All fractions must be between +1 and -1 inclusive; +1 is full heating, -1 is full cooling. 0 is no heating or cooling. BLAST constructs linear throttling ranges or dead bands between user-specified control points. For example, if the HEATANDCOOL profile (Figure 5) is used, heating is on any time the room temperature is 69°F (20.6°C) or below. At 67°F (19.4°C), the heating is operating at full capacity and a linear throttling range is used between 67 and 69°F (19.4 and 20.6°C). Thus, if the room temperature is 68.5°F (20.3°C), the heating is operating at 25 percent of capacity; at 68°F (20.0°C), it is operating at 50 percent capacity, and so on. With the HEATANDCOOL profile, no heating or cooling is accomplished between 69 and 77°F (20.6 and 25.0°C). A cooling throttling range is in effect between 77 and 79°F (25.0 and 26.1°C).

Deleting Schedules and Controls

Schedules and control strategies are deleted in the following way:

Name of schedule to be deleted

DELETE SCHEDULE (OFFICE OCCUPANCY): END SCHEDULE;
DELETE CONTROLS (NIGHT AND WEEKEND SETBACK WITH DUAL THROTTLING RANGES):

END CONTROLS;

A separate delete command is required for *each* schedule or control profile being deleted.

Volume II of the BLAST Users Manual lists the BLAST program's basic library. This library was created by running BLAST with library definitions as input. The input deck used to build the basic library is shown in Chapter 2 of Volume II, and contains hundred of examples of how to define entries for the various library subsets. A review of Volume II will help users prepare correct input for modifying the BLAST library.

Project Parameters

The last portion of the lead input (1) gives the project title, (2) extracts design day and location data from the BLAST library, (3) indicates the time period over which simulations are to be

performed if weather tapes are being used, and (4) provides ground temperatures to be used in the simulation.

The project title shown in the example below is merely the user-supplied title which will be reproduced periodically throughout BLAST printed repòrts.

Required punctuation

PROJECT = "MY PROJECT";

Up to three lines (240 characters) of user-supplied title or other information such as name of engineer, option being simulated, etc. The entire title must be within one set of quotation marks.

Data on several locations can be stored in the BLAST library. The location to be used in the current run of BLAST must be identified by the location command:

LOCATION = location name;

The location name corresponds to the name in the location subset of the library under which the appropriate latitude, longitude, and time zone data have been stored. For example:

Required punctuation

LOCATION = BOISE;

Name of location from location subset of BLAST library

The location command is only mandatory when weather tapes are not being used. Any time weather data tapes are used, the location data are taken from the weather tapes and the location command is ignored.

If one or more design days are to be specified, the design day command is required. For example:

DESIGN DAYS = usname1, usname2, . . . last name;

The words "usname1, usname2 . . . ," are the names of design days stored in the DESIGN DAY subset of the BLAST library. Up to 12 design days can be simulated in any one run. For example:

Required punctuation

DESIGN DAYS = BOISE WINTER, BOISE SUMMER;

Names of design day from the DESIGN DAYS subset of the BLAST library

The DESIGN DAYS command is ignored for any simulation using previously saved loads (i.e., ADD or REPLACE ZONES); instead, design day data from the saved loads file are used.

If the user wants a simulation to be made for a series of actual days on a weather tape, he/she must use the weather tape command. The weather tape command tells BLAST to read actual weather data from the weather tape or file:

WEATHER TAPE FROM usdate **THRU** usdate;

The word "usdate" is the user-supplied date of the first and last days of the period to be simulated. For example, to simulate the month of February, the following weather tape command could be appropriate:

Required punctuation

WEATHER TAPE FROM Ø1 FEB 65 THRU 28 FEB 65;

First day Last day

Note that the month must be designated by three letters with a space preceding and following them. Also, a weather tape or file must be attached at the time the BLAST program is run if the weather tape command is to have meaning (see Appendix B). Only one sequence of weather days can be specified in any one run. Both **DESIGN DAYS** and **WEATHER TAPE** can be used in the same BLAST run.

The last of the project parameters in lead input is ground temperatures. If slab-on-grade floors or basement walls are part of the building being simulated, ground temperatures to or from which slab-on-grade floors or basement walls will conduct heat must be specified:

GROUND TEMPERATURES = (usn1, usn2, . . . usn12);

The number "usn1" is the temperature in degrees Farenheit or Centigrade for January; usn2 is the temperature for February, and so on. Twelve months should be specified. If **GROUND TEMPERATURES** are not specified, the program supplies default values of 55°F (12.78°C). For example:

Required punctuation

GROUND TEMPERATURES = (4Ø, 42, 48, 55, 62, 67, 7Ø, 69, 63, 55, 48, 42) ;

Ground temperatures for each month, separated by commas

Ground temperatures are used as the surface temperatures for the outside of basement walls or the underside of slab-on-grade floors (see Appendix E for typical values). BLAST assumes that heat conduction through these surfaces occurs over their entire area. However, this may be inaccurate for large slabs. In this case, equivalent ground temperatures can be used to produce conduction losses (or gains) equivalent to the user's best estimate of the heat flow which will actually occur. Appendix E gives typical ground temperatures for many locations in the United States.

If slab-on-grade floors or basement walls are not present in the building being simulated, it is not necessary to specify ground temperatures.

Advanced Topics

Room Temperature Control

Control strategies contained in the BLAST library or defined by the user are used along with heating and cooling capacities for each zone in the building (see preceding section and Chapter 4). For example, to describe controls for one or more zones, the user might input:

CONTROLS = NIGHT AND WEEKEND SETBACK WITH DUAL THROTTLING RANGES, 80 HEATING, 100 COOLING;

This causes BLAST to use the control profiles shown in Figure 5 to add 80 kBtu/hr (23.4 kW) of heat to the room when full heating is required, or to remove 100 kBtu/hr (29.9 kW) of sensible heat from the room when full cooling is required. The heat balance point calculated by BLAST occurs at the temperature where the heat gains or losses to the *room air* exactly equal the cooling or heating capacity available *at that temperature.*

Figure 6 is the same as the HEATANDCOOL profile from Figure 5, except that the Y axis now shows zone capacities (+1 from Figure 5 is now 80 kBtu/hr [23.4 kW] and -1 is now -100 kBtu/hr [-29.3 kW]). The following heat balance points are also shown:

Point 1 might occur on a winter day. At Point 1, the room is at 68°F (20.0°C) and the heat loss from the room air exactly equals the room heating capacity available at 68°F (20.0°C). In this example, the room heating load (heat delivered to the zone) is 40 kBtu/hr (11.7 kW).

Point 2 might occur on a mild day in the spring or fall. At this point (73°F [22.8°C]), no room heating or cooling is accomplished by the building fan system (although heating or cooling energy may be consumed to heat or cool outdoor air). For the heat balance to occur at Point 2, room air convective heat gains caused by factors such as lights or occupancy must be balanced by convective heat losses to the walls or other room surfaces, or by infiltration losses. (Except for infilfiltration, convection is the only mechanism by which heat is transferred to the room air; radiant energy must first be absorbed by surfaces in the room before some or all of it is convected into the room air.) If there are heat gains to the room air, some or all of the surfaces surrounding the room air must be colder than 73°F (22.8°C) to allow the heat to escape by convection. The load at Point 2 is zero.

Point 3 shows a cooling condition. Here heat gains to the room air are balanced by the cooling capacity available at the balance point temperature.

Space temperature control is somewhat dependent on the type of system serving the space. The type of control strategy shown in Figures 5 and 6 approximates a single-zone drawthrough, package DX, or fan coil system. It does not apply to typical multizone, dual duct, or reheat systems, since a deadband is not possible with these types of systems.

System type can subtly affect room temperature control strategies. For example, assume that a package DX condensing unit with electric heat has been selected to serve the zone whose control strategy is shown in Figure 6. Further assume that the unit delivers 3850 cfm (1.82 m^3/s) to the space, that the cooling coil was selected to allow 55°F (12.8°C) air to be delivered at the design sensible load of 100 kBtu/hr (29.3 kW), and that the heating coil was selected to deliver 87.7°F (31°C) air at the design heating load of 80 kBtu/hr (23.4 kW). In this case, Figure 6 closely approximates the achieved room temperature control. The room thermostat will modulate the condensing unit from "off" to "full" capacity through as many capacity control steps as are available on the unit. This modulation will occur in a roughly linear fashion as the balance point room temperature varies from 77 to 79°F (25 to 26.1°C). The heating will be similarly modulated between 69 and 67°F (20.6 and 19.4°C), and both heating and cooling will be "off" between 69 and 77°F (20.6 and 25.0°C). Since the condensing unit's maximum heating and cooling capacity are approximately constant, the unit adds or removes fixed quantities of heat whenever the room temperature is below 67°F (19.4°C) or above 79°F (26.1°C).

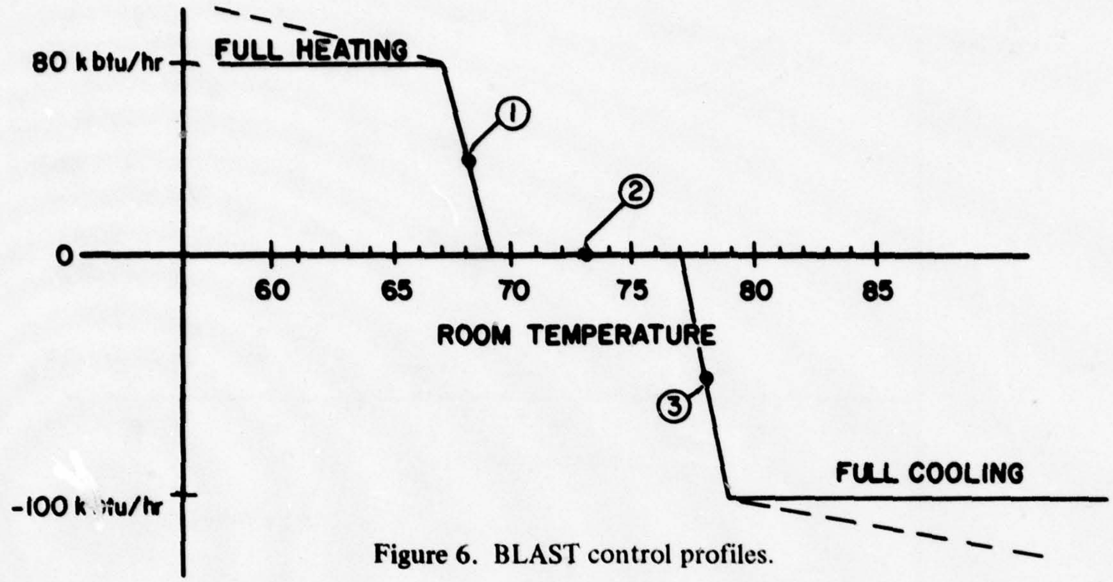


Figure 6. BLAST control profiles.

If a single-zone drawthrough unit served by hot and chilled water is selected instead of a package DX condensing unit, the control strategy of Figure 6 may require a slight revision. If room temperature remains between 67 and 79°F (19.4 and 26.1°C), Figure 6 is correct. However, as long as the boiler and chiller serving the coils in the fan unit can deliver constant temperature hot and chilled water, the maximum capacity of the heating and cooling coils is *not* independent of room temperature. For example, as the room temperature rises toward 79°F (26.1°C), the room thermostat opens the cooling coil's chilled water valve until the valve is fully opened at 79°F (26.1°C). If room heat gains are sufficient, the room air temperature will continue to rise; but as it rises, the temperature of the air entering the coil also rises. As a result, the cooling capacity of the coil gradually increases. The dotted lines on Figure 6 show this trend for both the heating and cooling coils. Coil catalog data can be used to determine the change in coil capacity that occurs with changing entering air conditions.

In the case of the single-zone drawthrough unit, the thermostat is in control of the heating and cooling capacity as long as sufficient capacity is available to keep the room temperature within the range of the thermostat (67 through 79°F [19.4 through 26.1°C] in the single-zone drawthrough example). Fortunately, most systems are designed with sufficient capacity to maintain comfort conditions, and users need only be concerned about room temperature control characteristics which are outside the range of the thermostat when the heating or cooling system has been inadvertently or deliberately undersized.

Figure 7 shows the equivalent HEATANDCOOL control profile that should be used if a three-deck multizone unit is selected to serve several zones with the same thermostat throttling ranges and deadband. The rationale for selecting this profile is (temperature ranges are shown on Figure 7):

1. Range 3 is the thermostat deadband in which almost all air delivered to the zone passes through the bypass deck of the three-deck multizone system and is neither heated nor cooled.

2. In Range 2, air from the hot deck and the bypass deck of the fan system are mixed to meet heating requirements in the zone. This is the heating throttling range for the thermostat. At its lower end (67°F [19.4°C]), all air to the zone comes from the hot deck and the air delivered to the zone is approximately at the hot deck temperature (87.7°F [31°C], for example).

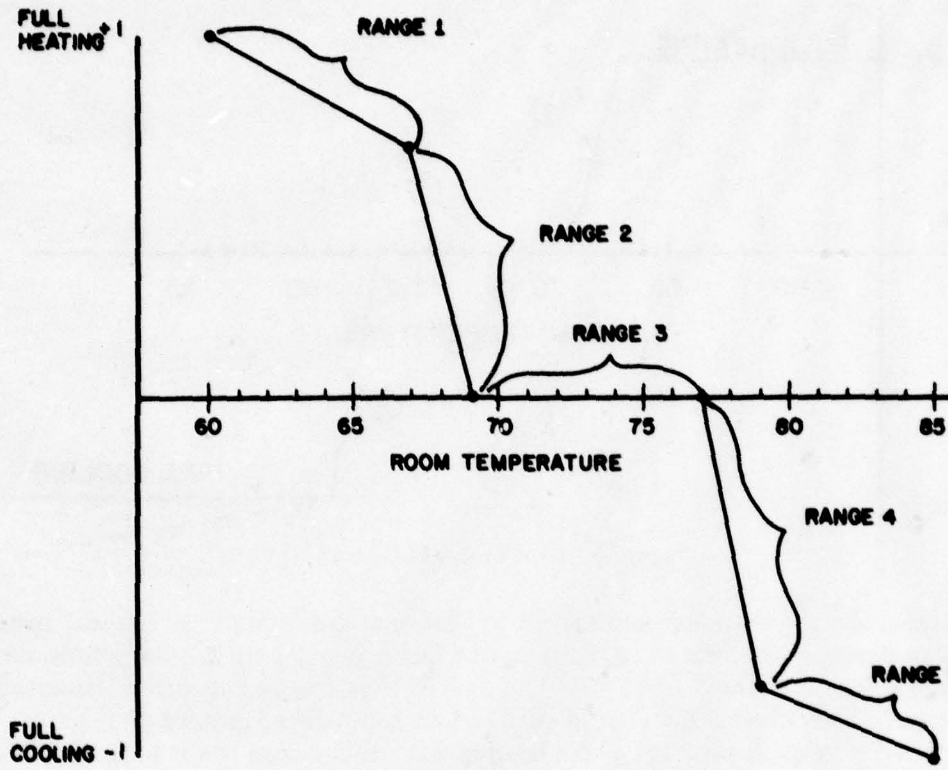


Figure 7. Typical control profile for three-deck multizone.

3. If heat losses are severe, the room temperature may continue to fall into Range 1. In this range, air entering the zone emanates from the hot deck only. As long as the fan system heating coil is not overloaded, the air is supplied to the zone at constant temperature. *However, the amount of heat added to the room air continues to increase as the room air temperature falls.* The amount of heat added per hour can be calculated from the following formula:

$$Q = \dot{m}C_p\,(T_S - T_R) \qquad \text{[Eq 1]}$$

where: $\dot{m}$ = mass flow rate of air supplied by the fan system to the room
C_p = specific heat of air
T_S = supply air temperature to the room (in this case, the hot deck temperature)
T_R = air temperature in the room

For this system, $\dot{m}$ and C_p are constant and T_S is constant for Range 1. Therefore, as the room temperature (T_R) falls, the heat added to the room increases linearly as shown in Figure 7.

4. Ranges 4 and 5 are analogous to Ranges 2 and 3, but are for cooling.

When defining a control profile like the one shown in Figure 7, users should select arbitrarily low and high room temperatures to establish the full heating and full cooling (+1 and −1) points on this profile. In the example above, 60 and 85°F (15.6 and 29.4°C) were selected. When specifying corresponding heating and cooling capacities for each zone (see Chapter 4), the "design" capacity generally should not be used. Capacity should correspond with the selected low and high temperatures.

In the DX condensing unit, single-zone drawthrough, and three-deck multizone examples, load calculations will yield identical results when the control profile shown in Figure 6 or Figure 7 is used, *providing* that the temperature in the space stays between 67 and 79°F (19.4 and 26.1°C) during the hours of the day when the control profile is in effect.

The same reasoning used for the three-deck multizone system can be used to construct control profiles for spaces served by conventional multizone, dual duct, or reheat systems (see Figure 8). Ranges 1 and 3 correspond to Ranges 1 and 5 of Figure 7, respectively. Range 2 covers the temperature range where the mixing box, zone dampers, or reheat coils are modulated by the room thermostat. No deadband is possible with these systems.

Figure 9 shows a typical control profile for a variable volume system with reheat. It was constructed based on the assumption that 3850 cfm (1.82 m^3/s) of 55°F (12.8°C) delivery air is to be supplied to the zone with the VAV dampers fully open at 79°F (26.1°C) and closed to their minimum of 20 percent at 77°F (25°C). Reheat is to operate between 69 and 67°F (20.6 and 19.4°C), and the reheat coil will deliver air at 140°F (60°C) when fully energized. Table 2 shows the calculation made to arrive at the control profile.

Even in the rather complicated case of the variable volume system, the profile shown in Figure 5 roughly approximates the profile of Figure 9 for room temperatures between 67 and 79°F (19.4 and 26.1°C). Therefore, loads calculated using the profile of Figure 5 can be used with reasonable accuracy to simulate package DX units, fan coil units, single-zone drawthrough units, or variable volume units *as long as room temperatures remain in the range of control of the room thermostat.*

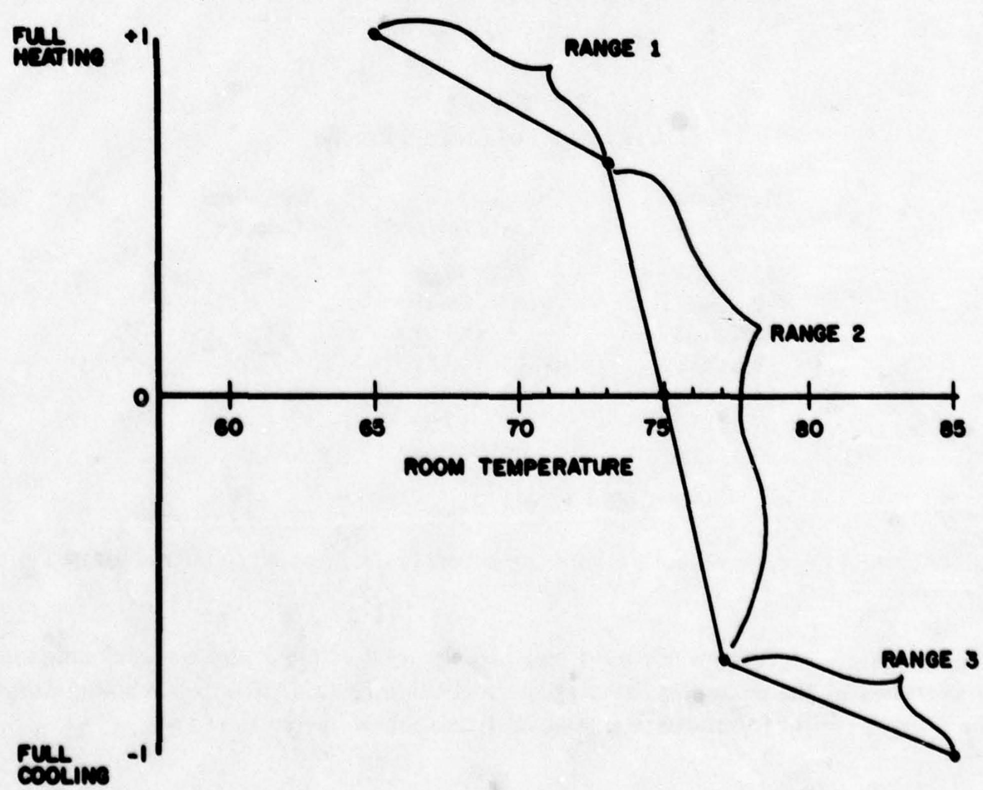


Figure 8. Control profile showing linear increase in heat added to room.

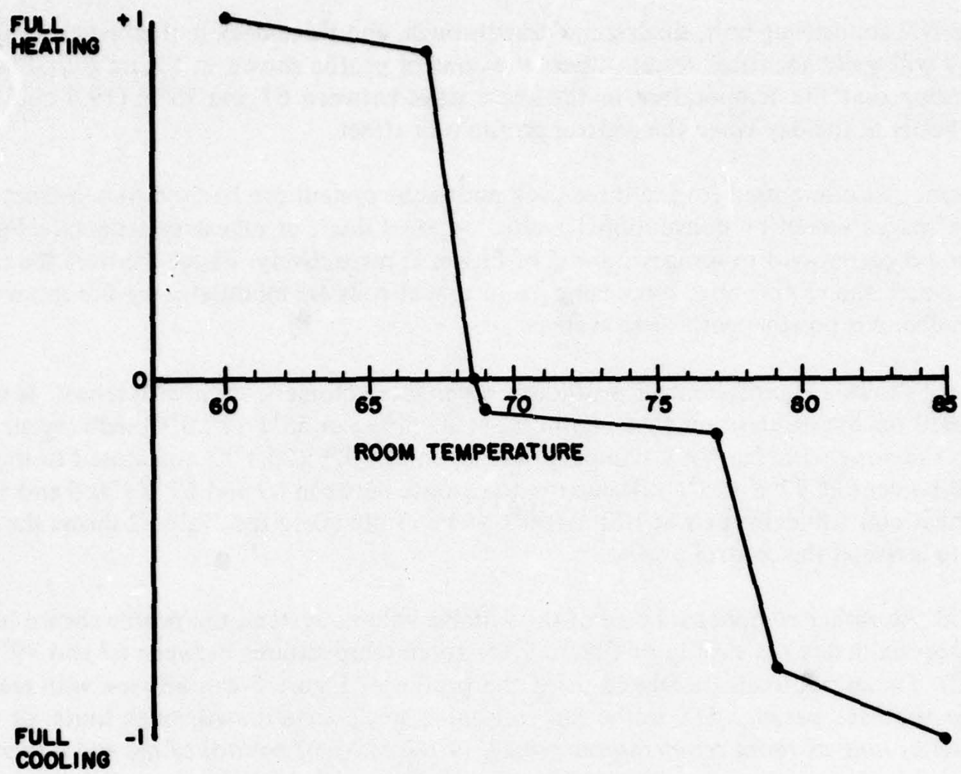


Figure 9. Typical control profile for VAV system.

Table 2
Calculation of Control Profile

Temperature °F (°C)	Capacity in kBtu/hr (kW)	Normalized Capacity
85.0 (29.4)	−125 (−36.6)	−1
79.0 (26.1)	−100 (−29.3)	− .8
77.0 (25)	− 18 (−5.3)	− .15
69.0 (20.6)	− 12 (−3.5)	− .09
68.7 (20.4)	0 (0)	0
67.0 (19.4)	61 (17.9)	.91
60.0 (15.6)	66 (19.3)	1.0

For multizone, dual duct, or reheat systems, however, loads must be calculated using a profile like that of Figure 8.

Setback control profiles, when used, are usually used at night and on weekends and can be specified as shown in the examples listed in the preceding section. However, cooling should be off during the setback period for multizone, dual duct, and reheat systems.

4 BUILDING DESCRIPTION

Introduction

The building description section of the BLAST input language is where the user provides all information concerning construction, orientation, and building usage necessary for BLAST to calculate heating and cooling loads. The building description block begins with the phrase

BEGIN BUILDING DESCRIPTION;

and ends with the phrase

END BUILDING DESCRIPTION;

Between the begin and end statements, certain global data are provided about the building and each zone is described.

The building or group of buildings being described is broken down into separate zones, generally on the basis of which areas are controlled by a single thermostat. Each zone is described separately, and BLAST does all calculations for each zone separately. In general, one zone has no effect on its neighbor during the calculation phase. However, heat transfer between zones of different temperatures can be accounted for using OTHER SIDE COEFFICIENTS (see Advanced Topics).

To accurately account for shading, solar gain, and the effects of wind on exterior walls, windows, and roofs, a fairly careful description of the building's geometry is required. Similarly, details about the building's construction are required to fully account for the time lag and heat flow through walls and for the heat stored in the building. These construction details are made available to the program by naming the appropriate wall, roof, or floor sections from the library.

In addition to geometric information, certain nongeometric data which affect the heat loss and gain in each zone must be provided. This includes information about such energy-influencing factors as lighting, equipment, people, and infiltration levels, and the appropriate schedule from the library which will be used in apportioning these factors each hour of each day. In addition, the room temperature control strategy must be specified. If outdoor air-controlled baseboard heat is used, it must be described to BLAST during the load calculation phase, since the amount of heat added to the space by this type of baseboard heating is independent of the room temperature, and like lights, equipment, and people, adds heat to the room air. (If baseboard heat is controlled by the room thermostat, it should be described under the fan system description; see Chapter 5.)

XYZ Coordinates

BLAST uses the Cartisian coordinate system for describing buildings and zones. The Y axis points due north, the X axis due east, and the Z axis points upward at right angles to the Y and X axes. Directions are specified as degrees clockwise from due north (the same as the compass); thus, east is either 90 or -270 degrees, south is ±180 degrees, and west is 270 or -90 degrees. For the purpose of calculating the effects of shading, sun, and wind, the direction toward which a wall faces must be accurately described.

When describing a building, an origin (usually the southwest corner of the building) is designated as the building origin. When describing zones, the location (origin) relative to this building origin is specified. Once a zone origin has been described, the user can ignore the rest of the building and give the coordinates of the surfaces bounding the zone relative to the zone origin.

The starting point of a surface is its lower left-hand corner, looking at it from the outside. In Figure 10, for example, the starting point of the south-facing wall of the upper right-hand zone is (0,0,0). This starting point is relative to the zone origin, which is (15,0,10). Once the user has established the starting point of a surface, the rest of the zone can be ignored and the surface treated as an XY plane with its starting point as (0,0). Thus, for example, the east-facing wall of the zone in Figure 10 starts at (15,0,0) relative to the zone origin. Viewing the wall as an XY plane, the window starts at (2,3). This window is actually 30 ft east, 2 ft north, and 18 ft above the building origin (9.1 m east, 0.6 m north, and 5.5 m above the building origin); however, the user never has to compute these distances–BLAST does it.

In summary, users begin with the building origin, locate and specify the zone origin, and describe the lower-left corner of each surface bounding the zone relative to the zone origin. Finally, viewing the lower-left corner of the surface as its origin, windows, doors, overhangs, and wings are described relative to that origin.

Global Specifications

Immediately following BEGIN BUILDING DESCRIPTION, four optional parameters can be specified before beginning the description of the building zones:

1. Building title

2. Dimensions

3. North axis

4. Description of any detached shading which might cast shadows on more than one zone in the building (detached shading is discussed under Advanced Topics).

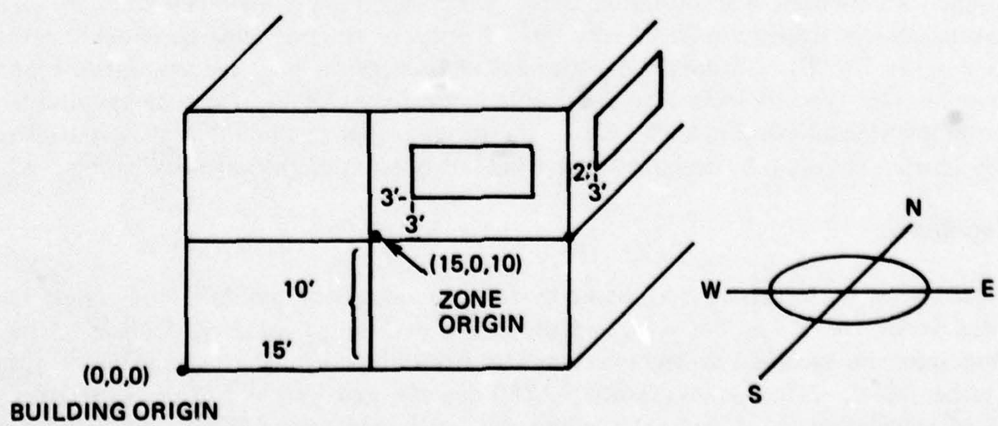


Figure 10. Building/zone origin description.

An optional building title which will appear on reports summarizing zone loads can be input as shown in the example below:

Required punctuation

BUILDING = "MY BUILDING";

User-supplied building title, 40 characters or less in quotes.

A dimension statement (see below) appears before any zone description and establishes names or dummy values which can later be used to describe dimensions within any or all of the zones.

Required punctuation

DIMENSIONS: N = Ø, E = 9Ø, W = 27Ø, S = 18Ø;

"Dummy dimensions separated by commas

The **NORTH AXIS** statement (see below) rotates the entire building the specified number of degrees; i.e., it establishes a new north axis which will usually correspond to a long line of the building. Its default value is 0. The **NORTH AXIS** statement is used because buildings frequently do not line up with true north. Figure 11 shows how the building north axis can be rotated to correspond with one of the major axes of an actual building.

Required punctuation

NORTH AXIS = 15;

Building north axis relative to true north

The order of specifying dimensions, north axis or detached shading is unimportant and any may be omitted.

Describing Zones

Zone Identifier

The description of a zone to the BLAST program begins with a zone identifier such as:

Required punctuation

ZONE 1 "LEFT END UNIT":

User-supplied zone number (integer)

User-supplied title, 40 characters or less in quotes.

The zone description ends with the phrase:

END ZONE;

All zones must be numbered, but not necessarily sequentially or in any particular order. The name for a space is always in quotes; names such as "PRESIDENT'S OFFICE"' "OFFICE 11," and

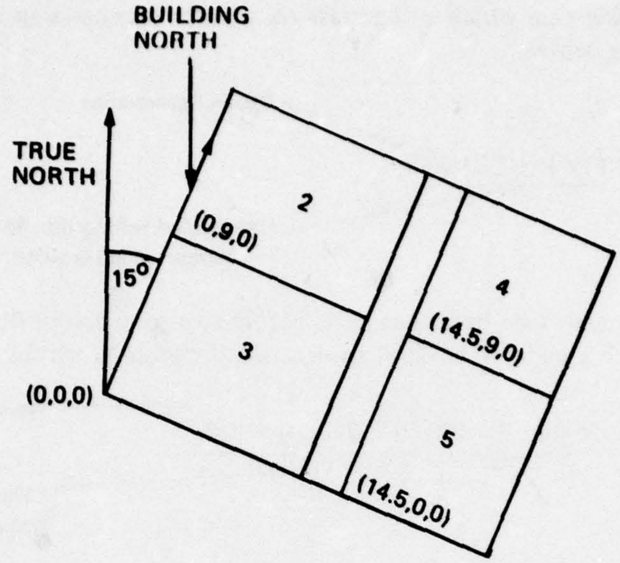


Figure 11. Example of north axis rotation.

"CORRIDOR," can be helpful in identifying zones. Each zone number must be unique; i.e., no two zones can have the same number.

Geometric Data

Before describing zone surfaces, the user has the option of (1) defining dummy dimensions to be used *only with that zone*, (2) defining the local origin for the zone relative to the building's origin, and (3) defining a north axis for the zone relative to the building's north axis. These optional commands parallel the dimensions and north axis commands that can be used before beginning a zone description. The optional commands help avoid repeating input for similar zones. The syntax for these commands is shown below:

ZONE 4 "Upper Office":

Required punctuation

ORIGIN: (Ø,55,Ø);

X,Y,Z co-ordinates relative to building origin

Required punctuation

NORTH AXIS = 18Ø;

Degrees from *building* north axis

Required punctuation

DIMENSIONS: L = 25;

Value of dummy dimension

User-selected dummy dimension, one word, 10 characters or less (L now stands for 25 ft [7.4 m] in this example). Can also override global dummy dimensions for only this zone by assigning new value here.

Again, DIMENSIONS, ORIGIN, and NORTH AXIS are optional specifications. ORIGIN defaults to (0,0,0) and NORTH AXIS defaults to 0 (relative to the building north axis).

Next, the types and geometry of the surfaces which enclose the zone or space being described are specified. The following is a sample of several surface definitions from zone 1 in Figure 12 (also see Figures 3 and 4, Chapter 2).

```
EXTERIOR WALLS:

    STARTING AT (0,0,0) FACING (180)
        EXTWALL04 (WIDTH1 BY HEIGHT1)
        WITH WINDOWS OF TYPE
        SINGLE PANE HW WINDOW (WIDTH2 BY HEIGHT2)
        at (2,2)
        WITH OVERHANG (WIDTH1 BY 3)
        AT (0, HEIGHT1),
    STARTING AT (0,25,0) FACING (270)
        EXTWALL04 (25 BY HEIGHT1);

PARTITIONS:

    STARTING AT (WIDTH1, 0, 0) FACING (90)
        PARTITION18 (25 BY HEIGHT1),
    STARTING AT (WIDTH1, 25,0) FACING (0)
        PARTITION18 (WIDTH1 BY HEIGHT1);

ROOF:

    STARTING AT (0, 0, HEIGHT1) FACING (180)
        ROOF04 (WIDTH1 BY 25);

SLAB ON GRADE FLOOR:

    STARTING AT (0,25,0) FACING (180)
        SLAB (WIDTH1 BY 25);
```

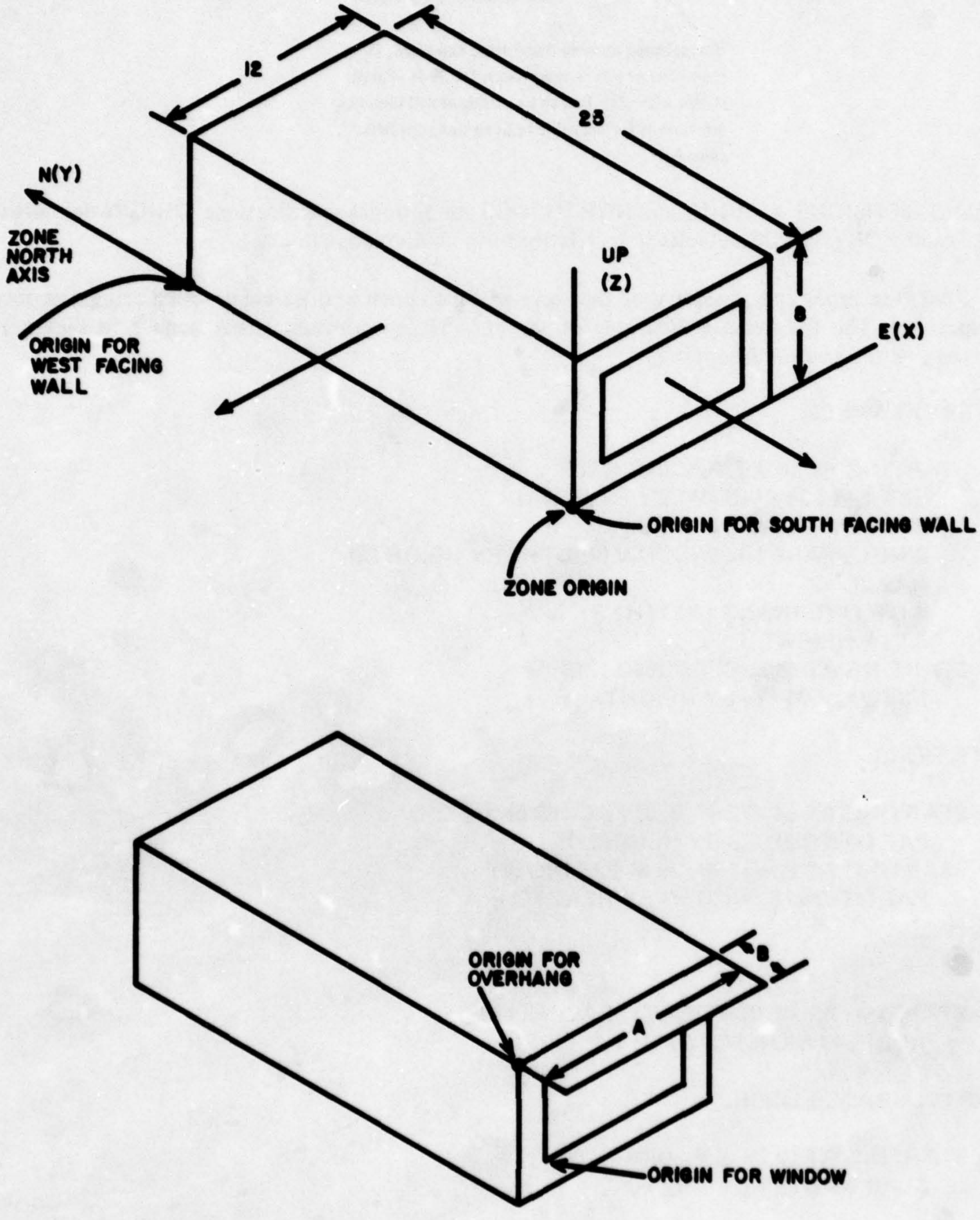


Figure 12. Origin and facing angles for walls, windows, and overhangs.

The sequence describing the exterior walls in Figure 12 has the following meaning:

STARTING AT (Ø,Ø,Ø) FACING (18Ø)

This sequence defines the location relative to the zone origin of the lower-left corner of the surface when viewed from the outside. In this case, the surface is 0 ft (0 m) from the zone origin in the X direction, 0 ft (0 m) in the Y direction, and 0 ft (0 m) in the Z direction.

The statement FACING (180) indicates the direction toward which the wall faces–due south or 180 degrees. This is the direction of the outward facing normal from the surface.

EXTWALLØ4 (WIDTH1 BY HEIGHT1) names the exterior wall and specifies its length and height. EXTWALLØ4 is a named wall section from the walls subset of the BLAST library. WIDTH1 and HEIGHT1 are global dummy dimensions.

WITH WINDOWS OF TYPE tells BLAST that this surface has a subsurface on it which is a window, and the window is a SINGLE PANE HW WINDOW (WIDTH2 by HEIGHT2)–WIDTH2 is the length of the window and HEIGHT2 is the height of the window. The statement AT (2,2) tells BLAST the location of the window relative to the lower-left corner of the wall. Similarly, WITH OVERHANG (WIDTH1 BY 3) AT (Ø, HEIGHT1) describes a shading surface which is assumed to shade only the south-facing wall and the window on the wall. The comma separates the description of one exterior wall from the next exterior wall, and a semicolon terminates the description of all exterior walls. Partitions are described in the same way as exterior walls.

The general syntax for describing all surface types is as follows (numbers to the left are referenced in the text but are not part of the language):

1. Surface type:
2. STARTING AT (usn1, usn2, usn3)
3. FACING (usn4)
4. TILTED (usn5)
5. usname1 (usn6 BY usn7)
6. OTHER SIDE COEFFICIENTS (a,b,c,d,e,f,g)
7. WITH subsurface
8. usname2 (usn8 BY usn9)
9. AT (usn10, usn11)
10. REVEAL (usn12)
11. AND (usn13, usn14)
12. WITH subsurface

13. usname3 (usn15 BY usn16)

14. AT (usn17, usn18)

•

•

•

The terms "usn1" through "usn18" are numbers or predefined dummy dimensions. The description of the last surface of a given surface type is terminated with a semicolon. Allowable surface types (statement 1, above) are:

ROOF:
CEILING:
CEILING UNDER ATTIC:
CRAWL SPACE CEILING:
EXTERIOR WALLS:
PARTITIONS:
WALLS TO UNCOOLED SPACES:
BASEMENT WALL:
FLOOR:
FLOOR OVER CRAWL SPACE:
SLAB ON GRADE FLOOR:
EXPOSED FLOOR:
ATTIC FLOOR:

These surface types have the following meaning:

CEILINGS, FLOORS, and PARTITIONS are assumed to divide temperature-controlled spaces (see Advanced Topics section of this chapter). Thus, in the absence of OTHER SIDE COEFFICIENTS, the program assumes that the surface temperatures on both sides of the surface are the same. This means that even though heat may be stored in a partition, ceiling, or floor, no heat flows *through* it. EXTERIOR WALLS, ROOFS, WALLS TO UNCOOLED SPACES, and EXPOSED FLOORS divide the temperature controlled space from the outside environment. EXTERIOR WALLS, EXPOSED FLOORS, and ROOFS feel the full effect of both solar radiation and outside temperature and the outside air film resistance for these surfaces changes with windspeed and wind direction. WALLS TO UNCOOLED SPACES are not affected by solar radiation and have constant outside convective air film resistance. BASEMENT WALLS and SLAB ON GRADE FLOORS separate the space from the earth surrounding the surfaces; therefore, the outside surface temperatures become the ground temperature. (A 1 to 2 ft [0.3 to 0.6 m] layer of earth is typically included for basement walls and slab floor construction when materials to be used for basement walls and slab floors are defined in the library.)

Attics and crawl spaces are simulated as separate zones (see Advanced Topics). The simulation of zones bounded by attics and crawl spaces requires a record of the surface temperatures on the outside of the ceiling under the attic or the floor over the crawl space. Hence, surfaces adjoining attics and crawl spaces require special names, i.e., CEILING UNDER ATTIC and FLOOR OVER CRAWL SPACE. For this same reason, ATTIC FLOOR and CRAWL SPACE CEILING must be used when attics and crawl spaces are described.

STARTING AT (usn1, usn2, usn3,) indicates the lower-left corner of the surface being described relative to the zone's origin. If this specification is omitted, the default value is 0,0,0.

FACING (usn4) indicates the direction towards which the surface faces; i.e., the direction of the outward pointing normal to the surface. The angle towards which a surface faces is the same one that would usually be used to describe the room; i.e., the north wall is the wall which faces northward.

TILTED specifies the angle from the Z axis (the upward pointing axis) and the outward pointing normal of the surface. If TILTED is omitted, tilts take on the following defaults: roofs and ceilings = 0 degrees, walls = 90 degrees, and floors = 180 degrees.

The WITH specification allows subsurfaces such as windows, doors, wings, and overhangs to be described. Allowable subsurface names are:

WINDOWS OF TYPE usname (width BY height)

DOORS OF TYPE usname (width BY height)

WINGS (width BY height)

OVERHANGS (width BY height)

The usnames (user-supplied names) above are window sections from the window subset of the library or door sections from the door subset of the library. The width and height of windows and doors are given immediately following their usname.

WINDOWS are the *only* subsurfaces which can transmit sunlight. Hence, glass doors should be described as windows.

The construction of wings and overhangs is not specified since they are only shading features. After a subsurface and its dimensions are specified, the location of the subsurface origin relative to the surface origin is specified by the AT command–i.e., AT (2,2)–and the optional REVEAL command (reveal is the distance a window or door is inset from the outside surface of the wall). The AND specification allows duplicate subsurfaces to be described by indicating only the location of their lower-left corner relative to the lower-left corner of the wall. The WITH command is repeated to describe several subsurfaces on any one surface.

If a roof or ceiling is flat, the angle towards which it is "facing" must be specified if the roof origin and dimensions are to have meaning. If a roof is peaked, it is easy to choose the facing direction and lower-left corners (see Figure 13). To specify the angle for a flat roof, the user pretends that it is slightly tilted in one direction of another. Then, by arbitrarily choosing an imaginary

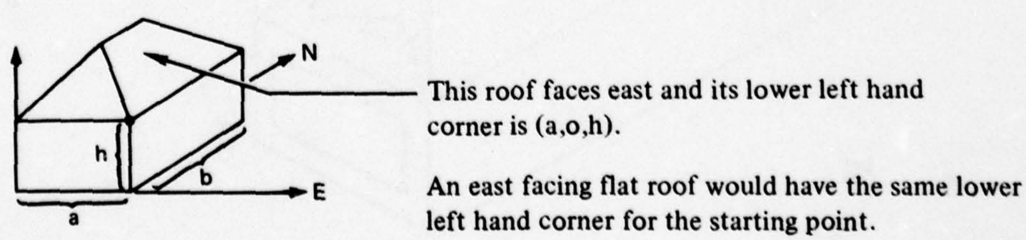


Figure 13. Peaked roof example.

tilt, the user can find the lower-left corner of the roof and establish its facing angle. The same procedure is used to specify floor angles. Figures 14 and 15 illustrate proper origins, facing angles, and dimensions for roof or ceilings and floors. Figures 16 and 17 show how the user may choose different origins, facing angles, and dimensions to describe the same roof and floor as those of Figures 14 and 15.

Wings and overhangs are rectangular, attached subsurfaces which project outward from the surface and shade only the surface (and its subsurfaces) to which they are attached. Thus, if a wall has an overhang, the overhang can only cast shadows onto the wall to which it is attached and onto doors or windows in that wall. (Surfaces which cast shadows onto more than one zone surface or onto several zones can be described as explained in the Advanced Topics section of this chapter.) If it is assumed that all surfaces are X-Y planes, then overhangs must *always* run parallel to the X axis (e.g., the length dimension of a wall); wings must run parallel to the Y axis (e.g., up and down a wall). To avoid confusion, the **AT** specification for wings and overhangs should contain the X and Y coordinates on the wall of the bottom-left corner of the wing or overhang. To specify the dimensions of wings and overhangs, first list the dimension along the surface (usually their long dimension), then list the distance the wing or overhang projects outward from the surface (see Figures 18, 19, and 20 for examples of origins and dimensions).

One zone surface can cast a shadow(s) on another zone surface(s). However, users need not worry about the effects of one wall shading another (e.g., an L-shaped zone). BLAST will automatically check for possible shadowing and perform the proper calculations. Also, since surfaces can only cast shadows in the hemisphere towards which they face, a roof or ceiling which faces *upward* will not cast a shadow *downward*. (Thus, specifying an oversized roof in an attempt to account for the shading effects of overhangs will *not* work.) Interior surfaces do not cast shadows of any kind. Thus, partitions, ceilings, and floors which divide conditioned spaces cannot cast shadows.

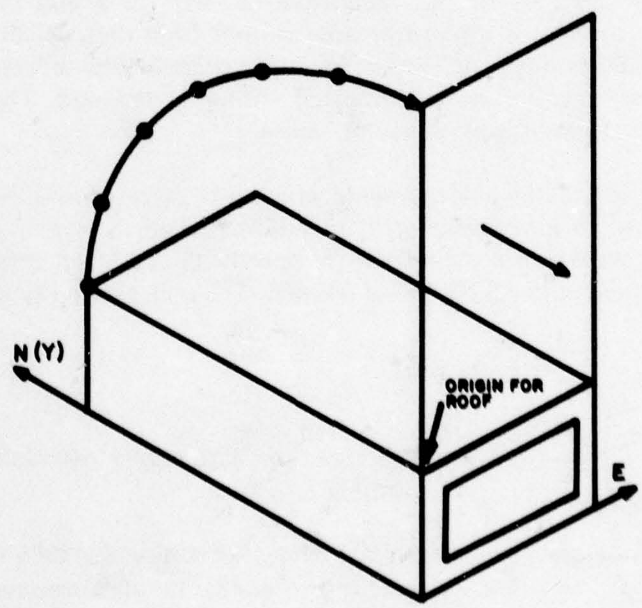


Figure 14. Origin and facing angles for south-facing roofs.

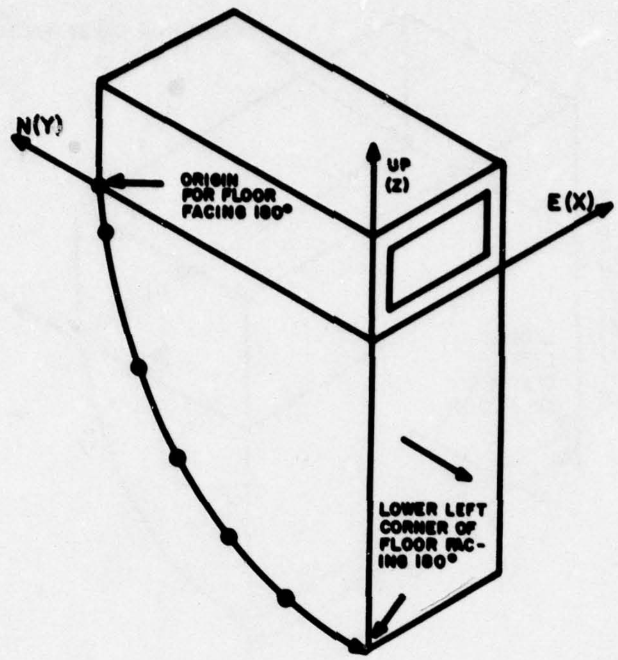


Figure 15. Origin and facing angle for south-facing floor.

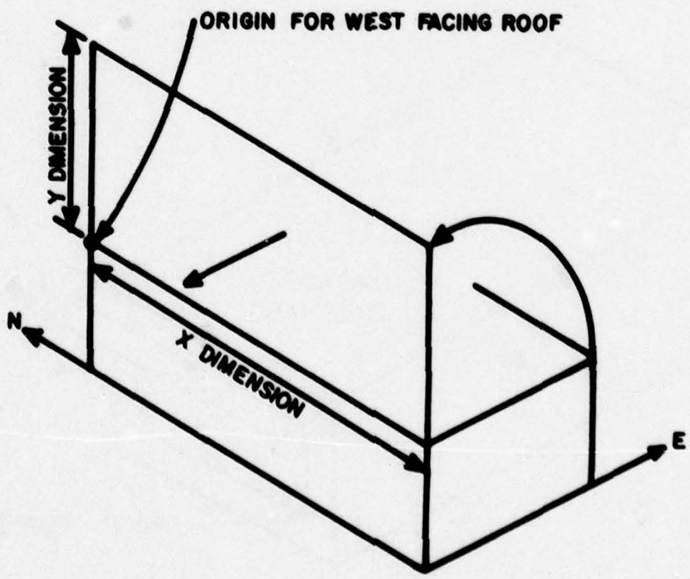


Figure 16. Origin and facing angle for west-facing roofs.

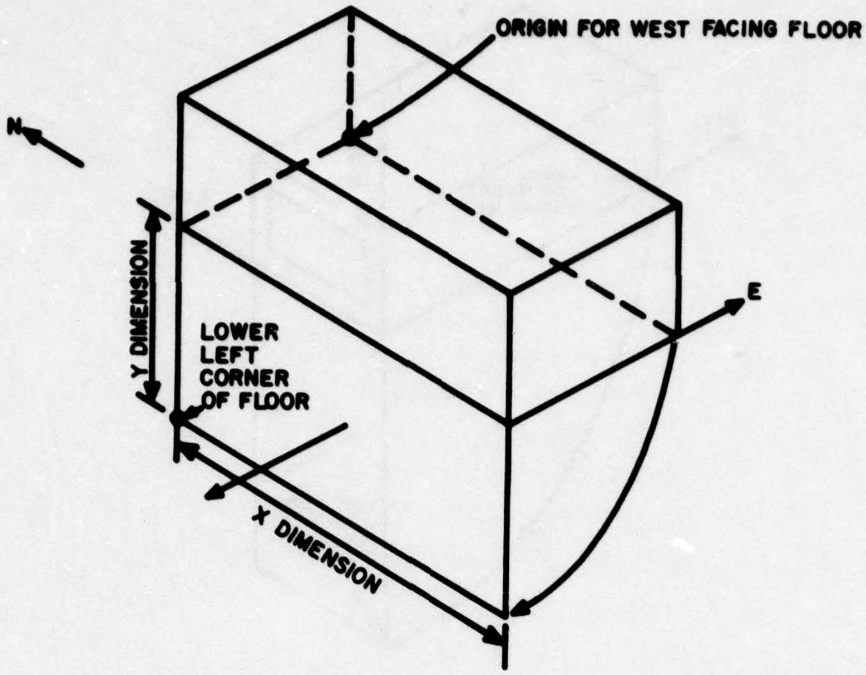


Figure 17. Origin and facing angle for west-facing floors.

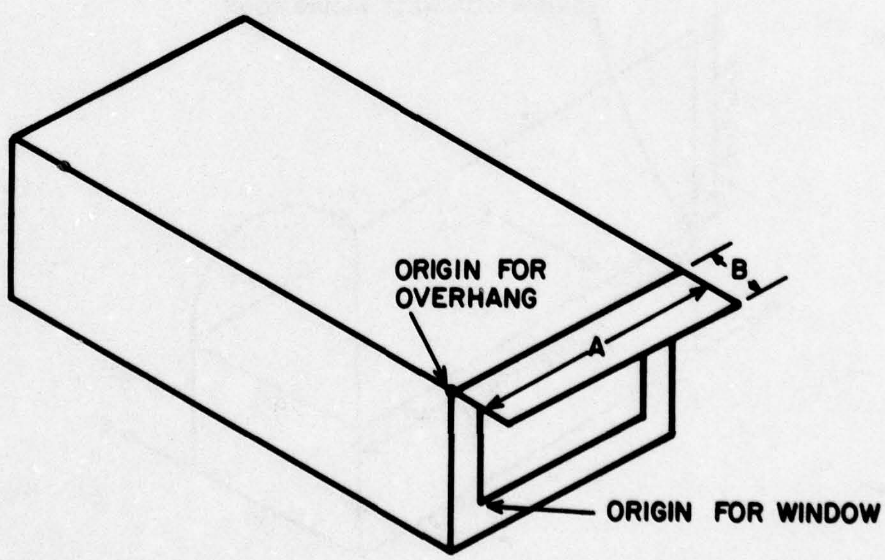


Figure 18. Wall with window and overhang (example problem).

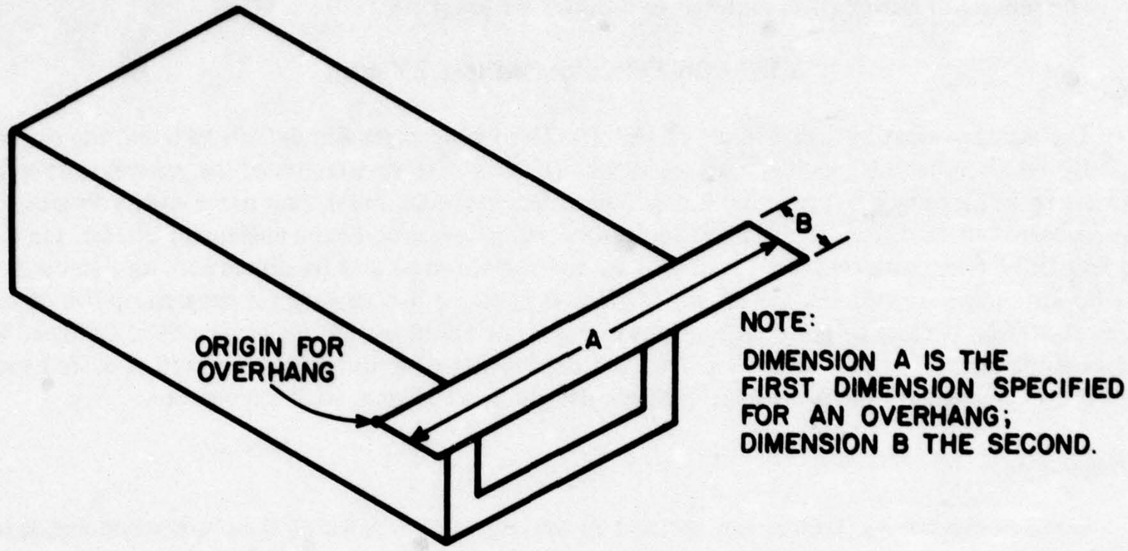


Figure 19. Overhang origin and dimensions.

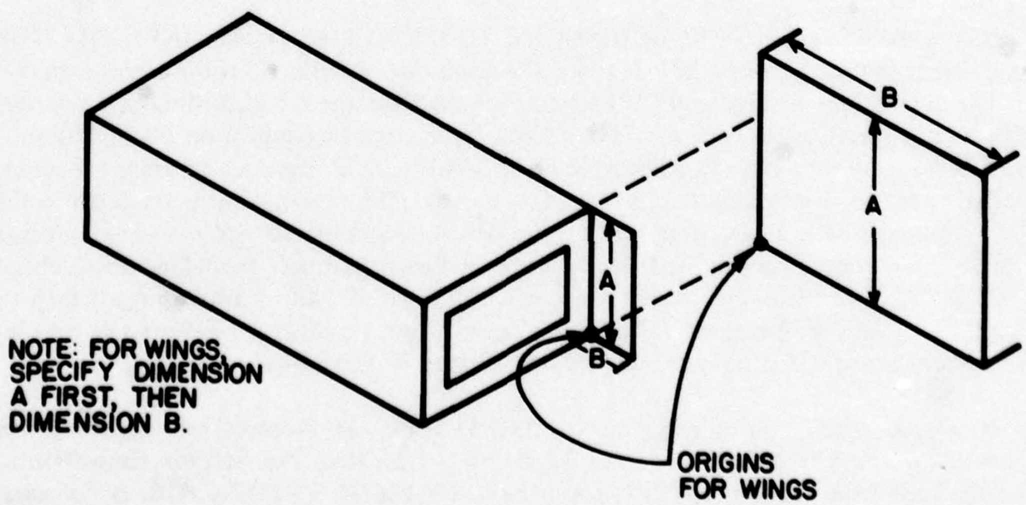


Figure 20. Origin and dimensions for wings.

The minimum information required to describe a surface is:

SURFACE TYPE: usname (usn BY usn);

The starting location will default to (0,0,0). The facing angle will default to 0 and the tilt will default according to the specified surface types. The first five statements of the general syntax for surfaces (p 53) are more or less order-independent. For example, the surface name and its dimensions can be indicated first, followed by the surface's starting location, facing angle, and tilt. Or, the facing and tilt can be indicated first, followed by the surface type and its dimension, and so on. It is not important which surfaces are described first. It is also not necessary for the description of surfaces of a given type to be contiguous. For example, one exterior wall can be described followed by the description of a partition followed by the description of another exterior wall *provided* each description begins with the proper surface type designation and ends with a semicolon.

Scheduled Loads

Seven nongeometric factors can be used to describe a zone; five of these are scheduled loads shown below:

PEOPLE = usn1, schedule1, AT ACTIVITY LEVEL, usn2, usn3, PERCENT RADIANT;

LIGHTS = usn4, schedule2, usn5 PERCENT RADIANT, usn6 PERCENT RETURN AIR, usn7 PERCENT LOST;

ELECTRICAL EQUIPMENT = usn8, schedule3, usn9 PERCENT RADIANT, usn10 PERCENT LATENT, usn11 PERCENT LOST;

GAS EQUIPMENT = usn12, schedule4, usn13 PERCENT RADIANT, usn14 PERCENT LATENT, usn15 PERCENT LOST;

INFILTRATION = usn16, schedule5, WITH COEFFICIENTS (A,B,C,D);

PEOPLE, LIGHTS, ELECTRIC EQUIPMENT, GAS EQUIPMENT, and INFILTRATION are all optional. Their default values are 0. If used, the minimum specifications for each of these statements are (1) the maximum value and (2) a schedule name from the schedule library. The schedules are hourly profiles specified for each day of the week and are used to apportion the maximum value given for each hour of each day. For example, if PEOPLE is used, the user provides the maximum number of people and a schedule name from the library. The user may also specify the activity level, i.e., the amount of heat given off per person per hour in kBtu/hr (kW). The default is 0.450 kBtu/hr (0.13 kW), the value for light office work (a factory worker would generate about 1.6 kBtu/hr [0.47 kW]). The amount of heat given off by people is split into sensible and latent components based on room temperature.[3] The user may also specify what percent of this heat is radiant. If the percent is not specified, a radiant default value of 70 percent is used.

The minimum specifications required for LIGHTS are (1) the total peak lighting level in kBtu/hr (or kW), and (2) a schedule name. If return air vents in the lighting fixture remove a portion of the heat from the room, this is specified as PERCENT RETURN AIR. If, for whatever reason, a portion of the lighting energy used is not added to the room or return air, this is specified

[3] *Carrier Handbook of Air Conditioning System Design* (McGraw-Hill, 1965), p 1-100.

as PERCENT LOST. PERCENT RADIANT is, as with people, the percent of the lighting energy that is radiant rather than convective; the default value is 50 percent. (100%–PERCENT LOST–PERCENT RETURN AIR–PERCENT RADIANT) becomes the instantaneous convective gain due to lights in any one hour according to the specified schedule. Radiant energy is assumed to fall uniformly on the surfaces of the space. Its effect on heat flow into the room air is accounted for through the room surface and room air heat balance.

ELECTRIC EQUIPMENT and GAS EQUIPMENT are specified in the same way as LIGHTS; however, PERCENT RETURN AIR is not allowed. PERCENT LATENT is the percentage of the equipment heat (if any) which enters the zone as moisture. Its default is 0. The default of radiant energy from equipment is 10 PERCENT RADIANT.

The minimum specifications required for INFILTRATION are (1) the peak infiltration in ft^3/min (m^3/s) and (2) a schedule name. The specification WITH COEFFICIENTS (A, B, C, D) is optional; these coefficients adjust the infiltration based on outdoor temperature and windspeed, (see Advanced Topics section of this chapter). Infiltration is often 0 for interior zones or zones that are pressurized by the building's fan system. However, users should select an appropriate infiltration rate and schedule for those periods when the fan in the building may be off and the building is not pressurized.

Baseboard Heating

Outdoor temperature controlled baseboard heating should be specified (if it is used) as follows:

BASEBOARD HEATING = (usn1 AT usn2, usn3 AT usn4);

where: usn1 and usn3 are baseboard heating capacities at the temperatures given by usn2 and usn4.

This statement describes a control schedule for baseboard heating based on outdoor temperature. A schedule such as (8 AT 0, 0 AT 55) would produce the strategy shown in Figure 21. Note that the baseboard heating capacity is specified in kBtu/hr (or kW).

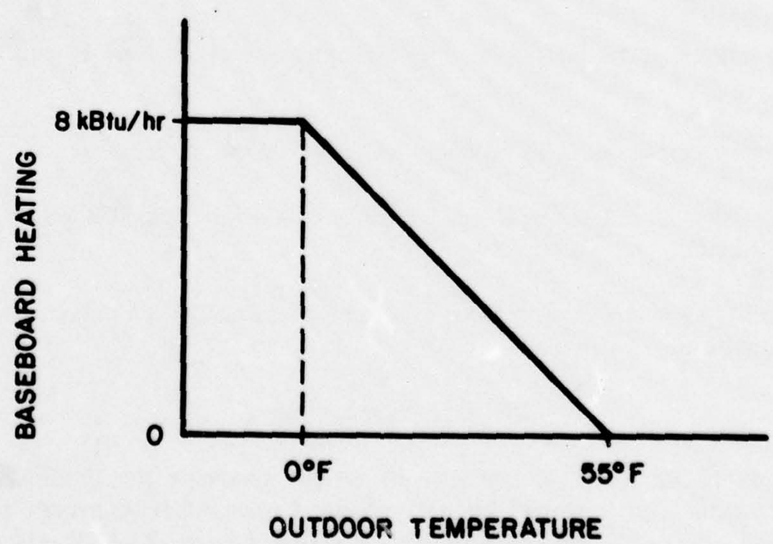


Figure 21. Baseboard heating vs outdoor temperature.

Room Temperature Control

The room temperature control strategy is specified by giving the library name for the temperature control strategy and by specifying the heating and cooling capacity in the following way:

CONTROLS = schedule, usn1 HEATING, usn1 COOLING;

This statement describes the thermostat setting and maximum heating and cooling capacities. Capacities (usn1 and usn2) are in kBtu/hr (or kW).

During the first run of the BLAST program for a new building, the user may not know what capacities should be installed in the building. In this case, omitting the heating and cooling capacity specification (i.e., CONTROLS = schedule;) causes BLAST to use a very large number (3142 kBtu/hr [1000 kW]). This will produce results indicating the peak heating and cooling required to maintain the room at a temperature very close to the desired set point. A check of the output will permit a determination of the required capacity. This can later be included in BLAST runs for annual calculations or in subsequent design day runs.

After all information needed for the zone description is input, the zone data block is terminated with the END ZONE; statement.

Similar Zones

If two zones are identical (or very nearly identical), only one need to be simulated during BLAST's load calculation phase. A zone multiplier can be used to describe the zone's fan system to account for the many zones which may be nearly or exactly identical to it. However, zones which are similar but face in different directions or have other different features are very quickly described by using the "same as" feature. For example:

ZONE 13 "MY ZONE":
ORIGIN: (Ø,Ø,Ø);
NORTH AXIS = 3Ø;
SAME AS ZONE 2 EXCEPT:
(any surfaces, nongeometric factors or other differences between zone 13 and zone 2)
END ZONE;

There are a few important rules to follow in using the "same as" feature:

1. If the user wishes to redescribe a single surface of a given type, all the surfaces of that type must also be redescribed.

2. If a user wants to delete any surfaces of a type that existed in a previously described zone, the following statement must be used:

DELETE surface type;

3. Users cannot change room dimensions by simply changing the DIMENSION statement. Any surface or subsurface dimensions that have changed must be redescribed. This is necessary because, when a dimension statement is used to describe a zone, BLAST replaces the dummy dimensions with the actual numbers as soon as they are encountered in a zone description. Thus,

changing the dimension statement will have no effect on the zone unless the changed dimensions are repeated in a description of the surfaces *after* the dimension statement is used.

The following description uses the "same as" feature to describe the simple four zone building shown in Figure 22.

```
BEGIN BUILDING DESCRIPTION;
DIMENSIONS: N=Ø, E=9Ø, S=18Ø, W=27Ø;
ZONE 1 "NORTHWEST OFFICE":
   ORIGIN: (Ø, 16, Ø);
   EXTERIOR WALLS:
.
.
   full description of zone 1
.
.
END ZONE;
ZONE 2 "NORTHEAST OFFICE":
   ORIGIN: (2Ø, 16, Ø);
   SAME AS ZONE 1 EXCEPT:
   EXTERIOR WALLS:
.
.
   redescribe exterior wall
.
.
   PARTITIONS:
.
.
   redescribe each partition;
.
.
END ZONE;
ZONE 3 "SOUTHWEST OFFICE":
   ORIGIN: (2Ø, 12, Ø);
   NORTH AXIS = 18Ø:
   SAME AS ZONE 2 EXCEPT:
END ZONE;
ZONE 4 "SOUTHEAST OFFICE":
   ORIGIN: (4Ø, 12, Ø);
   NORTH AXIS = 18Ø;
   SAME AS ZONE 1 EXCEPT:
END ZONE;
END BUILDING DESCRIPTION
```

The specifications for PEOPLE, LIGHTS, ELECTRICAL EQUIPMENT, GAS EQUIPMENT, INFILTRATION, and CONTROLS of each zone of the four-zone building described above are the same. In this case, zone 1 is identical to zone 4 except for its origin and the angle toward which its north axis is pointed. Similarly, zones 3 and 2 are identical except for their north axis relative to the

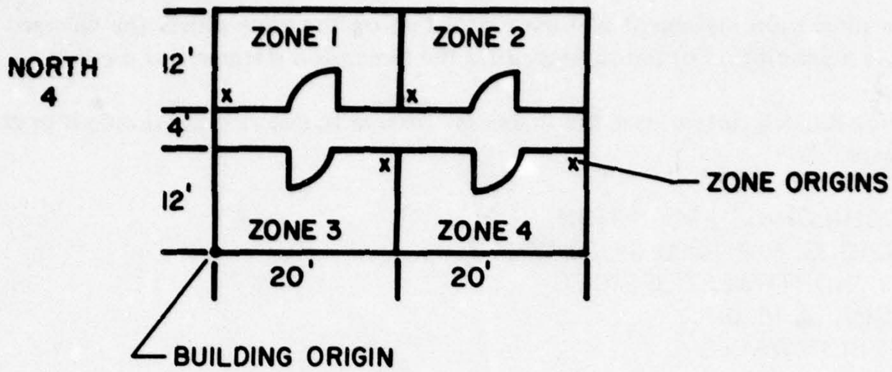


Figure 22. Example for describing zones using "same as."

building's north axis and their origin. Figure 22 shows how zone movement and rotation have been accomplished. For example, if the origin of zone 1 were moved to the origin shown for zone 4 and rotated 180 degrees, zone 1 would correspond exactly with zone 4. If zone 2's origin is then moved to the origin shown for zone 3 and rotated 180 degrees, zone 2's new description would be identical to the description of zone 3. Zone 2 is also described as being like zone 1; however, use of the "same as" feature in this case requires that the exterior walls and partitions be redescribed, since no possible combination of origin movement and north axis rotation will cause zone 1 to look like zone 2 (there is no mirror image command in the BLAST program).

Reports from the Building Loads Calculation Phase

The calculation of zone loads for each specified zone produces four default reports:

Surface of Zone summarizes zone surface data by printing type, area, U value, azimuth, tilt, and construction name for each surface (see Figure 23).

Schedule Loads for Zone gives the schedules and capacities for PEOPLE, LIGHTS, ELECTRIC EQUIPMENT, GAS EQUIPMENT, and INFILTRATION (see Figure 24).

Controlled Schedules of the Zone gives the heating and cooling capacities, on/off dates, control profiles, and daily schedules of control profiles (see Figure 25).

Load Summary for Zone reports the total heating and cooling energy required by the zone for the simulation period. Other elements of the report are (see Figure 26):

1. Latent Load is the energy equivalent of all internal moisture gains (not including infiltration latent gain).

2. Return Air Heat Gain is lighting energy which can be added directly to return air without contributing to the zone load.

3. Baseboard Load is energy added to the zone by outdoor air temperature controlled baseboard heating.

4. Electric Load is all energy used for lights and electric equipment.

Zone number — Zone name — Building name

SURFACES OF ZONE 1: LEFT END UNIT NEW OFFICE WEST WING

NUMBER	TYPE OF SURFACE TYPE OF SUBSURFACE	AREA	U	AZM	TILT	CONSTRUCTION
1	EXTERIOR WALL	64.0	.38	180.0	90.0	EXTWALL04
2	WINDOW	32.0	21.19	180.0	90.0	SINGLE PANE HW WINDOW
3	SHADOWING SUBSURFACE					
4	EXTERIOR WALL	200.0	.38	270.0	90.0	EXTWALL04
5	PARTITION	200.0	.49	90.0	90.0	PARTITION18
6	PARTITION	96.0	.49	0.	90.0	PARTITION18
7	ROOF	300.0	.09	180.0	0.	ROOF04
8	SLAB ON GRADE FLOOR	300.0	.09	180.0	180.0	SLAB

Units of ft^2 (or m^2)

Does not include film coefficients

Figure 23. Surfaces of Zone report.

SCHEDULED LOADS FOR ZONE 1 LEFT END UNIT

OCCUPANTS: DESIGN NUMBER = 2.0; ACTIVITY LEVEL = .450 1000BTUH; RADIANT FRACTION = .70

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SUN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MON	0.	0.	0.	0.	0.	0.	.10	.50	1.00	1.00	1.00	1.00	.50	1.00	1.00	1.00	.50	.10	0.	0.	0.	0.	0.	0.
TUE	0.	0.	0.	0.	0.	0.	.10	.50	1.00	1.00	1.00	1.00	.50	1.00	1.00	1.00	.50	.10	0.	0.	0.	0.	0.	0.
WED	0.	0.	0.	0.	0.	0.	.10	.50	1.00	1.00	1.00	1.00	.50	1.00	1.00	1.00	.50	.10	0.	0.	0.	0.	0.	0.
THU	0.	0.	0.	0.	0.	0.	.10	.50	1.00	1.00	1.00	1.00	.50	1.00	1.00	1.00	.50	.10	0.	0.	0.	0.	0.	0.
FRI	0.	0.	0.	0.	0.	0.	.10	.50	1.00	1.00	1.00	1.00	.50	1.00	1.00	1.00	.50	.10	0.	0.	0.	0.	0.	0.
SAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HOL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

LIGHTS: DESIGN OUTPUT = 1.70 1000BTUH; RADIANT FRACTION = .50; RETURN AIR FRACTION =0. ; FRACTION LOST =0.

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SUN	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
MON	.05	.05	.05	.05	.05	.05	.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.50	.05	.05	.05	.05	.05	.05
TUE	.05	.05	.05	.05	.05	.05	.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.50	.05	.05	.05	.05	.05	.05
WED	.05	.05	.05	.05	.05	.05	.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.50	.05	.05	.05	.05	.05	.05
THU	.05	.05	.05	.05	.05	.05	.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.50	.05	.05	.05	.05	.05	.05
FRI	.05	.05	.05	.05	.05	.05	.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.50	.05	.05	.05	.05	.05	.05
SAT	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
HOL	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05

ELECTRIC EQUIPMENT: DESIGN OUTPUT = 0. 1000BTUH; RADIANT FRACTION = .30; LATENT FRACTION =0. ; FRACTION LOST =0.

GAS EQUIPMENT: DESIGN OUTPUT = 0. 1000BTUH; RADIANT FRACTION = .30; LATENT FRACTION =0. ; FRACTION LOST =0.

INFILTRATION: DESIGN FLOW = 20. CFM

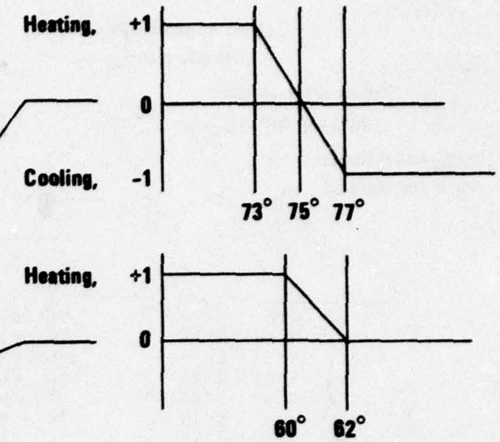
HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SUN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MON	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TUE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WED	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
THU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FRI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SAT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
HOL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

These schedules are not printed since maximum capacities are zero for ELECTRIC EQUIPMENT and GAS EQUIPMENT in this example.

Figure 24. Scheduled Loads for Zone report.

```
CONTROL SCHEDULES FOR ZONE     1  LEFT END UNIT

HEATING CAPACITY =   1.600E+01 1000BTUH
COOLING CAPACITY =   8.000E+00 1000BTUH

HEATING TURNED ON  JAN  1
HEATING TURNED OFF DEC 31
COOLING TURNED ON  JAN  1
COOLING TURNED OFF DEC 31

CONTROL PROFILES FROM MAXIMUM HEATING TO MAXIMUM COOLING
 PROFILE NUMBER - (TEMPERATURE/FRACTION ON FULL CAPACITY)

   1 -     73.00/ 1.00    75.00/ 0.      75.02/-0.      77.00/-1.00
   2 -     60.00/ 1.00    62.00/ 0.
  10 -     32.00/ 0.      32.00/ 0.
```

No heating or cooling, default value.



CONTROL SCHEDULES: PROFILES FOR EACH HOUR OF EACH DAY

DAY -	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SUN -	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
MON -	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
TUE -	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
WED -	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
THU -	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
FRI -	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
SAT -	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HOL -	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Figure 25. Control Schedules for Zone report.

LOADS SUMMARY FOR ZONE 1: LEFT END UNIT NEW OFFICE WEST WING

COLUMBIA WINTER

MO DY HR	HEATING LOAD (BTU)	COOLING LOAD (BTU)	LATENT LOAD (BTU)	RETURN AIR HEAT GAIN (BTU)	BASEBOARD LOAD (BTU)	ELECTRIC LOAD (BTU)	GAS LOAD (BTU)	INFILT HEAT LOSS (BTU)	INFILT HEAT GAIN (BTU)	MAT/ H EX	ODH/ H ON	OWH/ C ON	C EX
1 21 1	6.673E+03	0.	0.	0.	0.	8.500E+01	0.	2.444E+03	0.	61.2	8.6	16.2	
1 21 2	6.904E+03	0.	0.	0.	0.	8.500E+01	0.	2.518E+03	0.	61.1	7.6	16.2	
1 21 3	7.121E+03	0.	0.	0.	0.	8.500E+01	0.	2.578E+03	0.	61.1	6.8	16.2	
1 21 4	7.319E+03	0.	0.	0.	0.	8.500E+01	0.	2.623E+03	0.	61.1	6.2	16.2	
1 21 5	7.479E+03	0.	0.	0.	0.	8.500E+01	0.	2.637E+03	0.	61.1	6.0	16.2	
1 21 6	7.577E+03	0.	0.	0.	0.	8.500E+01	0.	2.605E+03	0.	61.1	6.4	16.2	
1 21 7	7.614E+03	0.	0.	0.	0.	8.500E+01	0.	2.527E+03	0.	61.0	7.4	16.2	
1 21 8	7.569E+03	0.	0.	0.	0.	8.500E+01	0.	2.390E+03	0.	61.1	9.2	16.2	
1 21 9	6.918E+03	0.	0.	0.	0.	8.500E+01	0.	2.204E+03	0.	61.1	11.8	16.2	
1 21 10	6.054E+03	0.	0.	0.	0.	8.500E+01	0.	2.000E+03	0.	61.2	14.8	16.2	
1 21 11	5.261E+03	0.	0.	0.	0.	8.500E+01	0.	1.782E+03	0.	61.3	18.2	16.2	
1 21 12	4.728E+03	0.	0.	0.	0.	8.500E+01	0.	1.589E+03	0.	61.5	21.4	16.2	
1 21 13	3.670E+03	0.	0.	0.	0.	8.500E+01	0.	1.451E+03	0.	61.5	23.8	23.6	
1 21 14	3.381E+03	0.	0.	0.	0.	8.500E+01	0.	1.362E+03	0.	61.6	25.4	24.6	
1 21 15	3.410E+03	0.	0.	0.	0.	8.500E+01	0.	1.329E+03	0.	61.6	26.0	25.0	
1 21 16	3.842E+03	0.	0.	0.	0.	8.500E+01	0.	1.360E+03	0.	61.5	25.4	24.6	
1 21 17	4.845E+03	0.	0.	0.	0.	8.500E+01	0.	1.435E+03	0.	61.4	24.0	23.7	
1 21 18	4.998E+03	0.	0.	0.	0.	8.500E+01	0.	1.562E+03	0.	61.4	21.8	23.7	
1 21 19	5.243E+03	0.	0.	0.	0.	8.500E+01	0.	1.721E+03	0.	61.3	19.2	23.7	
1 21 20	5.486E+03	0.	0.	0.	0.	8.500E+01	0.	1.887E+03	0.	61.3	16.6	23.7	
1 21 21	5.726E+03	0.	0.	0.	0.	8.500E+01	0.	2.033E+03	0.	61.3	14.4	23.7	
1 21 22	5.979E+03	0.	0.	0.	0.	8.500E+01	0.	2.171E+03	0.	61.3	12.4	23.7	
1 21 23	6.225E+03	0.	0.	0.	0.	8.500E+01	0.	2.284E+03	0.	61.2	10.8	23.7	
1 21 24	6.455E+03	0.	0.	0.	0.	8.500E+01	0.	2.371E+03	0.	61.2	9.6	23.7	
FINAL	1.400E+05	0.	0.	0.	0.	2.040E+03	0.	4.886E+04	0.	0	24	0	0

MAXIMUM HEATING LOAD = 7.614E+03 AT HOUR 7 ON DAY 21 OF MONTH 1 WITH A ZONE AIR TEMP OF 61.05
MAXIMUM COOLING LOAD = 0. AT HOUR 0 ON DAY 0 OF MONTH 0 WITH A ZONE AIR TEMP OF 0.
MAXIMUM ZONE AIR TEMP = 6.158E+01 AT HOUR 14 ON DAY 21 OF MONTH 1
MINIMUM ZONE AIR TEMP = 6.105E+01 AT HOUR 7 ON DAY 21 OF MONTH 1

INFILTRATION HEAT GAIN/LOSS REFERS TO SENSIBLE PORTION ONLY.
LATENT PORTION IS COMPUTED BY AIR HANDLING SYSTEM SUBPROGRAM.
LOSS = MASS FLOW * SPECIFIC HEAT * (ZONE TEMP - OUTSIDE TEMP)
IT IS INCLUDED IN TOTAL SENSIBLE LOAD.

Outside wet bulb temperature (OWB)

Outside dry bulb temperature (ODB)

Zone mean air temperature (MAT)

The effects of these items *are* included in the heating and cooling loads.

These items *are not* included in the zone heating and cooling loads. They are accounted for during system simulation.

Figure 26. Loads Summary for Zone report.

LOADS SUMMARY FOR ZONE 1: LEFT END UNIT NEW OFFICE WEST WING

COLUMBIA SUMMER

MO DY HR	HEATING LOAD (BTU)	COOLING LOAD (BTU)	LATENT LOAD (BTU)	RETURN AIR HEAT GAIN (BTU)	BASEBOARD LOAD (BTU)	ELECTRIC LOAD (BTU)	GAS LOAD (BTU)	INFILT HEAT LOSS (BTU)	INFILT HEAT GAIN (BTU)	MAT/ H EX	ODH/ H ON	OWB/ C ON	C EX
7 21 1	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.0	75.9	72.9	
7 21 2	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	85.7	74.8	72.6	
7 21 3	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	85.3	73.9	72.4	
7 21 4	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	84.8	73.2	72.2	
7 21 5	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	84.4	73.0	72.1	
7 21 6	0.	0.	6.061E+01	0.	0.	3.400E+02	0.	0.	0.	84.6	73.4	72.3	
7 21 7	0.	4.711E+03	2.247E+02	0.	0.	1.700E+03	0.	0.	0.	76.2	74.5	72.6	
7 21 8	0.	4.544E+03	4.336E+02	0.	0.	1.700E+03	0.	0.	7.456E+00	76.1	76.5	73.1	
7 21 9	0.	4.479E+03	4.329E+02	0.	0.	1.700E+03	0.	0.	6.784E+01	76.1	79.4	73.9	
7 21 10	0.	4.517E+03	4.325E+02	0.	0.	1.700E+03	0.	0.	1.442E+02	76.1	82.7	74.8	
7 21 11	0.	4.596E+03	4.327E+02	0.	0.	1.700E+03	0.	0.	2.396E+02	76.2	86.4	75.8	
7 21 12	0.	4.618E+03	2.165E+02	0.	0.	1.700E+03	0.	0.	3.383E+02	76.2	89.9	76.7	
7 21 13	0.	4.834E+03	4.332E+02	0.	0.	1.700E+03	0.	0.	4.165E+02	76.2	92.6	77.4	
7 21 14	0.	4.947E+03	4.342E+02	0.	0.	1.700E+03	0.	0.	4.710E+02	76.2	94.3	77.8	
7 21 15	0.	5.036E+03	4.348E+02	0.	0.	1.700E+03	0.	0.	4.916E+02	76.3	95.0	78.0	
7 21 16	0.	4.949E+03	2.176E+02	0.	0.	1.700E+03	0.	0.	4.706E+02	76.2	94.3	77.8	
7 21 17	0.	0.	4.348E+01	0.	0.	8.500E+02	0.	0.	0.	85.7	92.8	77.4	
7 21 18	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	85.5	90.4	76.8	
7 21 19	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	85.9	87.5	76.1	
7 21 20	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.1	84.7	75.3	
7 21 21	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.4	82.2	74.7	
7 21 22	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.5	80.0	74.1	
7 21 23	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.4	78.3	73.6	
7 21 24	0.	0.	0.	0.	0.	8.500E+01	0.	0.	0.	86.3	77.0	73.3	
FINAL	0.	4.723E+04	3.797E+03	0.	0.	1.921E+04	0.	0.	2.647E+03	0	0	10	0

```
MAXIMUM HEATING  LOAD =  0.          AT HOUR  0 ON DAY  0 OF MONTH  0 WITH A ZONE AIR TEMP OF  0.
MAXIMUM COOLING  LOAD =  5.036E+03 AT HOUR 15 ON DAY 21 OF MONTH  7 WITH A ZONE AIR TEMP OF 76.27
MAXIMUM ZONE AIR TEMP =  8.647E+01 AT HOUR 22 ON DAY 21 OF MONTH  7
MINIMUM ZONE AIR TEMP =  7.613E+01 AT HOUR  9 ON DAY 21 OF MONTH  7

INFILTRATION HEAT GAIN/LOSS REFERS TO SENSIBLE PORTION ONLY.
LATENT PORTION IS COMPUTED BY AIR HANDLING SYSTEM SUBPROGRAM.
LOSS = MASS FLOW * SPECIFIC HEAT * (ZONE TEMP - OUTSIDE TEMP)
IT IS INCLUDED IN TOTAL SENSIBLE LOAD.
```

Add these numbers to get total hours heating is on.

Add these numbers to get total hours cooling is on.

Number of hours that cooling exceeds 99% of cooling capacity.

Number of hours cooling is on and capacity not exceeded.

Number of hours heating is on and capacity not exceeded.

Number of hours that heating exceeds 99% of heating capacity.

Appears only when there is a cooling load.

Appears only when there is a heating load.

Total energy into gas equipment.

Total energy into lighting and electrical equipment.

Figure 26. (Cont'd).

LOADS SUMMARY FOR ZONE 1: LEFT END UNIT NEW OFFICE WEST WING

WIFE TRY TEST RUN

MO DY HR	HEATING LOAD (BTU)	COOLING LOAD (BTU)	LATENT LOAD (BTU)	RETURN AIR HEAT GAIN (BTU)	BASEBOARD LOAD (BTU)	ELECTRIC LOAD (BTU)	GAS LOAD (BTU)	INFILT HEAT LOSS (BTU)	INFILT HEAT GAIN (BTU)	MAT/ H EX	ODB/ H ON	OWB/ C ON	C EX
1	3.741E+06	0.	7.457E+04	0.	0.	4.410E+05	0.	1.177E+06	0.	0	708	0	0
2	3.148E+06	0.	6.782E+04	0.	0.	4.026E+05	0.	1.038E+06	0.	0	688	0	0
3	1.549E+06	1.740E+04	7.274E+04	0.	0.	4.238E+05	0.	5.123E+05	5.890E+02	0	497	23	0
4	5.928E+05	1.909E+04	7.700E+04	0.	0.	4.389E+05	0.	2.029E+05	1.509E+03	0	291	32	0
5	1.934E+05	1.005E+05	7.810E+04	0.	0.	4.410E+05	0.	7.092E+04	4.572E+03	0	144	86	0
6	8.154E+03	5.550E+05	7.401E+04	0.	0.	4.046E+05	0.	4.475E+03	2.278E+04	0	8	192	0
7	0.	7.297E+05	8.213E+04	0.	0.	4.410E+05	0.	0.	2.066E+04	0	0	220	0
8	2.675E+01	6.585E+05	8.166E+04	0.	0.	4.410E+05	0.	6.147E+02	2.840E+04	0	1	219	0
9	3.844E+04	2.030E+05	7.183E+04	0.	0.	4.046E+05	0.	2.304E+04	4.731E+03	0	48	152	0
10	4.801E+05	9.123E+04	7.417E+04	0.	0.	4.238E+05	0.	1.666E+05	4.305E+03	0	247	66	0
11	1.899E+06	1.687E+04	6.891E+04	0.	0.	4.046E+05	0.	5.675E+05	0.	0	606	9	0
12	3.482E+06	0.	7.142E+04	0.	0.	4.238E+05	0.	1.086E+06	0.	0	727	0	0
FINAL	1.517E+07	2.391E+06	8.944E+05	0.	0.	5.091E+06	0.	4.850E+06	8.755E+04	0	3965	999	0

MAXIMUM HEATING LOAD = 1.554E+04 AT HOUR 8 ON DAY 31 OF MONTH 12 WITH A ZONE AIR TEMP OF 73.06
MAXIMUM COOLING LOAD = 5.186E+03 AT HOUR 15 ON DAY 23 OF MONTH 8 WITH A ZONE AIR TEMP OF 76.30
MAXIMUM ZONE AIR TEMP = 8.740E+01 AT HOUR 21 ON DAY 21 OF MONTH 7
MINIMUM ZONE AIR TEMP = 6.061E+01 AT HOUR 8 ON DAY 7 OF MONTH 1

INFILTRATION HEAT GAIN/LOSS REFERS TO SENSIBLE PORTION ONLY.
LATENT PORTION IS COMPUTED BY AIR HANDLING SYSTEM SUBPROGRAM.
LOSS = MASS FLOW * SPECIFIC HEAT * (ZONE TEMP - OUTSIDE TEMP)
IT IS INCLUDED IN TOTAL SENSIBLE LOAD.

Figure 26. (Cont'd).

5. Gas Load is all energy used for gas equipment.

6. Infiltration Heat Loss and Infiltration Heat Gain are sensible infiltration losses and gains which contribute to the heating or cooling load, respectively.

The Load Summary Zone report also lists 24 hours of zone mean air temperature (MAT), outdoor dry bulb (ODB), and outdoor wet bulb (OWB) for design days. For longer weather tape runs, the number of hours required for heating (H ON) and cooling (C ON) and the number of hours the heating and cooling capacity are exceeded (H EX and C EX) are reported. Maximum heating and cooling loads and maximum and minimum zone air temperatures for the period of simulation are also reported.

Advanced Topics

Detached Shading

For many buildings, solar flux can have a major impact on building load. Earlier in this chapter, subsurfaces such as overhangs and wings which can shade a zone surface are described. Surfaces of a zone that casts shadows onto other surfaces of that zone are handled automatically by BLAST. In addition, users may describe adjacent buildings or other significant shadow casting features not attached to a particular zone and which can shade more than one zone or more than one zone surface. A detached shading device—regardless of type—casts a shadow only in the hemisphere toward which it faces.

The syntax for describing detached shading is:

DETACHED SHADING "usname": (usn1 BY usn2)

STARTING AT (usn3, usn4, usn5)

FACING (usn6)

TILTED (usn7);

Detached shading surfaces are described in much the same way as zone surfaces. However, all detached shading surfaces start at a point relative to the general building origin and have a facing angle relative to the *building's north axis.* (If tilt is not specified, a default tilt angle of 90 degrees is used.)

Since detached shading is not part of the zone description, it must appear outside any zone description, i.e., before or between the zone descriptions. Detached shading should be described before simulating a zone in which its effects are important.

While "detached" implies that shading surfaces are not part of the building, the detached shading sequence can be used to describe attached shading surfaces which may shade more than one zone. For example, one wing of a building might shade several zones of another wing. Detached shading surfaces cast shadows only when the sun is behind them (as determined by their facing angle); therefore, a wall described as a detached shading surface will not shade itself. For this reason, detached objects which cast shadows in an arc of more than 180 degrees when viewed from above should be described as several detached shading surfaces with different facing angles and origins.

In Figure 27, the east-facing wall of the south wing of the building is shaded by the east wing of the building during the early morning. The south wall of the west wing is shaded by the south wing for most of the afternoon. The user should define detached shading to account for this as follows:

```
DETACHED SHADING: "EAST WING":
  (45 by 75)
  STARTING AT (45, 3Ø, Ø)
  FACING (18Ø);
DETACHED SHADING: "SOUTH WING":
  (3Ø by 75)
  STARTING AT (45, Ø, Ø)
  FACING (9Ø);
```

Attics and Crawl spaces

Attics and crawl spaces represent special kinds of zones. Usually, but not necessarily, they are unheated and uncooled. They are generally separated from conditioned spaces by an ATTIC FLOOR or CRAWL SPACE CEILING. These zones are simulated to more accurately account for heat flow to the zones below and above them. They are identified and described in the same way as other zones; however, an attic or crawl space description begins with ATTIC or CRAWL SPACE instead of ZONE. In addition, instead of FLOOR or SLAB-ON-GRADE-FLOOR, attic descriptions use ATTIC FLOOR (an attic can have one and only one surface designated as ATTIC FLOOR). The surface temperature for ATTIC FLOOR is calculated and stored for each hour; it is later used as the outside surface temperature of CEILING UNDER ATTIC when any zone below an attic is described. Similarly, the description of a crawl space can have one and only one CRAWL SPACE CEILING. The crawl space ceiling surface temperature is stored and becomes the surface temperature for the outside of a FLOOR OVER CRAWL SPACE when any zone above a crawl space is described.

If not otherwise specified by the user, crawl space ceilings or attic floors are assumed to transfer heat to and from a zone above or below them, respectively. This zone is assumed to have a temperature between 68 and 79°F (20 and 26°C) depending on outside air temperature.* A mean air film resistance value between the surface and the room air above or below the surfaces of 1.46 Btu/hr sq ft°F (8.34 W/m^2°K) is used in calculating surface heat flow.

Other Side Coefficients

Ordinarily, the BLAST program assumes that the temperature outside a partition is equal to the temperature on the inside, since partitions are assumed to separate conditioned spaces. Therefore, although there is storage capacity, there is no heat flow through a partition. However, in many cases, partitions separate rooms of widely varying temperatures, e.g., kitchens or equipment rooms. In such cases, the user will have to specify a method for estimating the "other side" temperature, since BLAST considers only one zone at a time. OTHER SIDE COEFFICIENTS provides the means

*The room air temperature is set equal to the outside air temperature but has upper and lower bounds of 79 and 68°F (26 and 20°C), respectively.

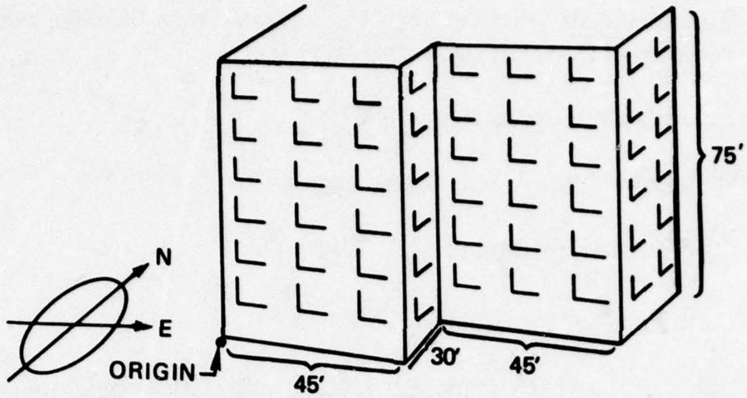


Figure 27. Example for detached shading.

by which the user controls the simulation of temperatures and heat flow between the zone being described and its neighbor(s). OTHER SIDE COEFFICIENTS may also be used with any other surface type except CEILING UNDER ATTIC and FLOOR OVER CRAWL SPACE. OTHER SIDE COEFFICIENTS affects the "other side" of a surface in the following way:

OTHER SIDE COEFFICIENTS (C_1, C_2, C_3, C_4, C_5, C_6, C_7)

Each coefficient has a special meaning. Since *position* is very important, if the user does not want to use a particular coefficient, he/she should enter a 0 to hold its place.

C_1 – the first value can have two meanings. If it is greater than 0, then it is a surface film coefficient. BLAST will use the remaining terms to first calculate the outside *air* temperature, then calculate the outside *surface* temperature based on the air temperature and the film coefficient C_1. If C_1 is less than or equal to 0, BLAST will use the remaining terms to calculate the *surface* temperature (*not* the outside air temperature).

C_2 – zone air temperature factor

C_3 – ambient dry bulb weighting factor

C_4 – constant temperature weighting factor

C_5 – constant temperature to be used with the C_4 weighting factor

C_6 – ground temperature weighting factor

C_7 – windspeed modifier.

The coefficients listed above are used in the following equation:

$$T = \frac{(C_2 * T_{ZONE} + C_3 * T_{OADB} + C_4 * C_5 + C_6 * T_{GRND} + C_7 * W_{SPD} * T_{OADB})}{(C_2 * C_3 + C_4 + C_6 + C_7 * W_{SPD})} \qquad \text{(Eq 2]}$$

where: T = the outside air temperature if C_1 is greater than 0 or the outside surface temperature of C_1 is less than or equal to 0.

T_{ZONE} = the zone air temperature in °F (°C)

T_{OADB} = the outdoor air dry bulb temperature in °F (°C)

T_{GRND} = the ground temperature in °F (°C)

W_{SPD} = the wind speed in ft/min (m/sec).

Example 1: if the user wishes to describe a kitchen wall, he/she must know its "other side" temperature; i.e., the temperature of the surface of the wall inside a conditioned zone that adjoins the kitchen. If the space next to the kitchen is at approximately 70°F (21°C), the following OTHER SIDE COEFFICIENTS might be used:

OTHER SIDE COEFFICIENTS = (1.46, 0, 0, 1, 70, 0, 0)

In this case, the air temperature on the other side of the kitchen wall will be 1 X 70 or 70°F (21°C). The 1.46 is the air film coefficient used to calculate the actual surface temperature in Btu/hr sq ft °F (8.34 W/m²°K).

Example 2: To describe the zone next to the kitchen, the user must know the approximate kitchen temperature. The user may specify:

OTHER SIDE COEFFICIENTS = (1.46, 0, 0, 1, 80, 0, 0)

In this case, the kitchen is assumed to be at about 80°F (27°C) most of the time. Again, the film coefficient for the surface film of the kitchen wall is 1.46 Btu/hr sq ft °F (8.34 W/m²°K).

Example 3: If an oven is against a wall in the kitchen that adjoins the zone in question:

OTHER SIDE COEFFICIENTS = (0, 0, 0, 1, 150, 0, 0)

In this case, the first coefficient is 0; hence, when simulating the zone adjacent to the kitchen, the partition between the zone and kitchen is assumed to have an outside *surface* temperature of 150°F (65.5°C).

Example 4: If there is an unusual exterior wall for which the default value for the outside film coefficient (adjusted to account for windspeed) is not appropriate (e.g., a wall to an adjoining garage), the user can use OTHER SIDE COEFFICIENTS. For example:

OTHER SIDE COEFFICIENTS = (1.46, 1, 1, 0, 0, 0, .001)

BLAST would then calculate the equivalent outside air temperature for the wall as follows:

$$T = \frac{1 * T_{ZONE} + 1 * T_{ODB} + .001 * W_{SPD} * T_{ODB}}{1 + 1 + .001 * W_{SPD}} \qquad \text{[Eq 3]}$$

For the following windspeeds, Table 3 lists the values for the outside air temperature.

Table 3
Outside Air Temperature

Windspeed MPH (km/hr)	Windspeed ft/min (m/s)	Outside Air Temperature, T
0	0	$1/2\ T_{ZONE} + 1/2\ T_{ODB}$
11	1000	$1/3\ T_{ZONE} + 2/3\ T_{ODB}$
23	2000	$1/4\ T_{ZONE} + 3/4\ T_{ODB}$
34	3000	$1/5\ T_{ZONE} + 4/5\ T_{ODB}$

In this case, the outside air temperature is specified, *not* the surface temperature (which is attenuated by a 1.46 convective heat transfer coefficient).

The user can choose whatever method best reflects his/her estimate of the surface conditions. It is unlikely that all seven terms would be needed at any one time; therefore, zeros must be entered to hold the places of the terms not used.

If OTHER SIDE COEFFICIENTS is used for exterior walls, solar flux effects are not considered. Since subsurfaces have the same kind of OTHER SIDE COEFFICIENTS as their base surface, a window on a surface with OTHER SIDE COEFFICIENTS will not transmit solar flux either.

Infiltration Equation

Earlier in this chapter, infiltration was specified by listing a peak value, schedule name, and (optionally) by specifying infiltration coefficients. These optional coefficients can also be used to determine the actual infiltration.* The equation is as follows:

$$I_{ACT} = I_{MAX} * F_{SCH} * (A + B * [T_{ZONE} - T_{ODB}] + C * W_{SPD} + D * W_{SPD}^2) \qquad \text{[Eq 4]}$$

where: I_{ACT} = the actual infiltration

I_{MAX} = the maximum infiltration specified by the user

F_{SCH} = fractional infiltration from the user-specified library schedule

T_{ZONE} = the inside temperature

T_{ODB} = the outside temperature

*Empirical equation and the coefficient default values were determined from ASHRAE journal articles and other data on the effects of outdoor weather conditions.

W_{SPD} = the windspeed

A = first user-specified coefficient; default value = 0.606

B = second user-specified coefficient; default value = 0.0202 (1/°F) (0.036[1/°C])

C = third user-specified coefficient; default value = 0.000598 min/ft (0.1177 s/m)

D = fourth user-specified coefficient; default value = 0.00.0 min^2/sq ft (0.0 s^2/m^2).

Users who wish to have a constant infiltration rate (subject to the schedule used for infiltration) should set A equal to 1 and the other coefficients equal to 0.

Nonrectangular Surfaces

So far, all the surfaces have been described as rectangles (length by height). Many buildings have nonrectangular surfaces, such as attic gables. BLAST provides an alternate method of describing a surface to handle these situations.

Figure 28 the STARTING AT point represents the origin of the X,Y plane (point 1) and one of the vertices of the surface. The points (20,0) and (10.5) represent the other vertices with respect to the origin of the surface. The rest of the surface description is the same as it was for rectangular surfaces. Notice, however, that vertices are always specified in the plane for the surface being described and require extra care in calculating the vertices relative to the surface origin whenever a TILT is specified for a surface.

BLAST also allows a fourth vertex so that the user can describe any four-sided surface as long as it is not concave; concave surfaces must be broken down into allowable convex shapes and described as more than one surface (see Figure 29).

Figure 30 is an example of a description of a surface with four vertices. Figure 31 shows how a detached shading device can be described as a nonrectangular surface.

Optional Reports

In addition to the default reports previously described, BLAST will, on request, print the following optional reports:

WALLS – This report option gives a detailed description of the building surfaces. It describes the material layers and their thermal properties and lists the conduction transfer functions which define the time dependent thermal conductivity of the surface. It also gives the optical properties of all window types. This report enables the user to verify that the simulation has used the correct parameters for the building surface. (See Figure 32).

ZONE – This report produces a plan view of the heat transfer surfaces of the zone and lists the coordinates of the vertices of all zone surfaces. It is useful in checking that the geometry of the zone has been properly described. The line printer sketch of the zone plan gives a quick indication of error; the report of the surface vertices can be used to determine which surface is mispositioned. (See Figures 33 and 34.)

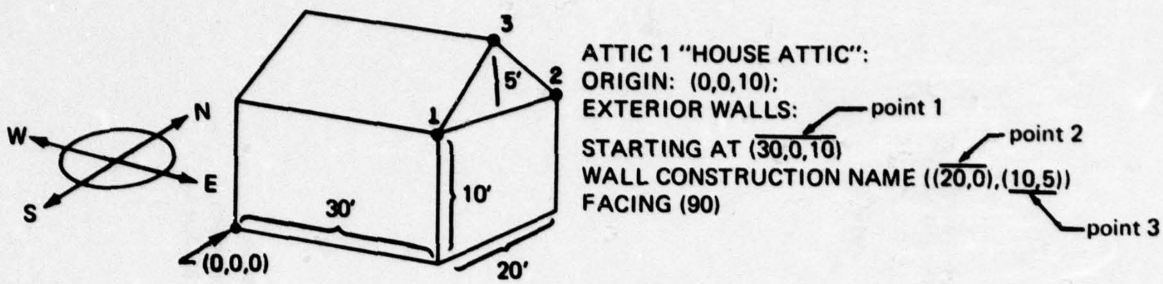


Figure 28. Example 1, nonrectangular surfaces.

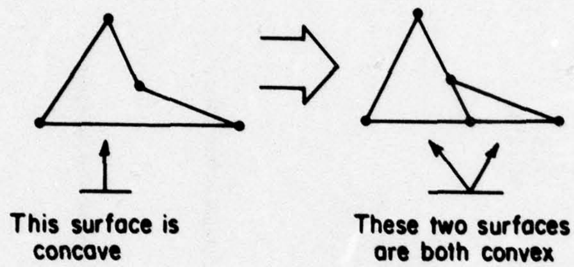


Figure 29. Example 2, nonrectangular surfaces.

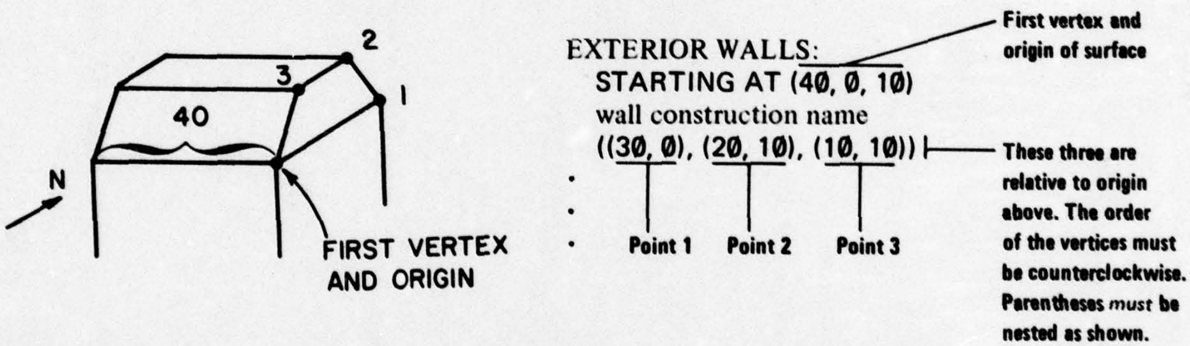


Figure 30. Example 3, nonrectangular surfaces.

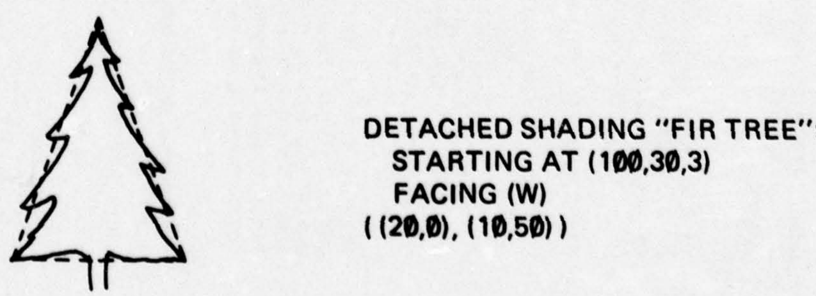


Figure 31. Example 4, nonrectangular surfaces.

CONDUCTIVE PROPERTIES OF HEAT TRANSFER SURFACE

EXTWALL04

DESCRIPTION OF CONSTRUCTION

LAYER	THICKNESS FEET	CONDUCTIVITY BTU/(HR*FT*F)	DENSITY LB/FT**3	SPECIFIC HEAT BTU/(LB*F)	RESISTANCE HR*FT**2*F/BTU
A2 - 4 IN DENSE FACE BRICK	.3330	.720	130.000	.220	0.
B1 - AIRSPACE RESISTANCE	0.	0.	0.	0.	.910
C8 - 8 IN HW CONCRETE BLOCK	.6670	.600	61.000	.200	0.
E1 - 3 / 4 IN PLASTER OR GYP BOARD	.0625	.420	100.000	.200	0.

5 CONDUCTION TRANSFER FUNCTIONS OF ORDER 3

TIME	INTERNAL	CROSS	EXTERNAL	FLUX
1	3.17916040	.00070729	5.11536610	1.30730104
2	-6.06304030	.00401738	-9.85850555	-.47580314
3	3.69687270	.02934427	5.88137905	.03974731
4	-.80310946	.01315937	-1.15849630	
5	.03901732	.00167253	.06915754	

THERMAL CONDUCTANCE = .380 BTU/(HR*FT**2*F)
OUTER THERMAL ABSORPTANCE = .90
OUTER SOLAR ABSORPTANCE = .93
INNER THERMAL ABSORPTANCE = .90
INNER SOLAR ABSORPTANCE = .92
OUTER SURFACE ROUGHNESS: ROUGH

Number of hours of flux history

U value *without* inside and outside air film resistance

Number of hours of temperature history

Reference for the use of higher order transfer functions is:
B.A. Peavy, "A Note on Response Factors and Conduction Transfer Functions," ***ASHRAE Transactions,*** **Vol 84, Part 1.**

Figure 32. WALLS report.

```
DUMP OF SURFACE VERTICES OF ZONE      1:  LEFT END UNIT

NS ORG  DIRECTION COSINES    COORDINATES

1 ABS  0.     -1.000 0.      (  0. ,   0. ,   8.0) (  0. ,   0. ,   0. ) ( 12.0,   0. ,   0. ) ( 12.0,   0. ,   8.0)
2 REL  0.     -1.000 0.      (  2.0,   6.0,   0. ) (  2.0,   2.0,   0. ) ( 10.0,   2.0,   0. ) ( 10.0,   6.0,   0. )
3 REL  0.      0.    -1.000  (  0. ,   8.0,   8.0) (  0. ,   8.0,   0. ) ( 12.0,   8.0,   0. ) ( 12.0,   8.0,   8.0)
4 ABS -1.000   0.     0.     (  0. ,  25.0,   8.0) (  0. ,  25.0,   0. ) (  0. ,   0. ,   0. ) (  0. ,   0. ,   8.0)
5 ABS  1.000   0.     0.     ( 12.0,   0. ,   8.0) ( 12.0,   0. ,   0. ) ( 12.0,  25.0,   0. ) ( 12.0,  25.0,   8.0)
6 ABS  0.      1.000  0.     ( 12.0,  25.0,   8.0) ( 12.0,  25.0,   0. ) (  0. ,  25.0,   0. ) (  0. ,  25.0,   8.0)
7 ABS  0.      0.     1.000  (  0. ,  25.0,   8.0) (  0. ,   0. ,   8.0) ( 12.0,   0. ,   8.0) ( 12.0,  25.0,   8.0)
8 ABS  0.      0.    -1.000  (  0. ,   0. ,   0. ) (  0. ,  25.0,   0. ) ( 12.0,  25.0,   0. ) ( 12.0,   0. ,   0. )
```

Origin.

ABS means relative to building origin and REL means relative to lower left corner of base surface

Surface number

There may be either 3 or 4 coordinates, as;

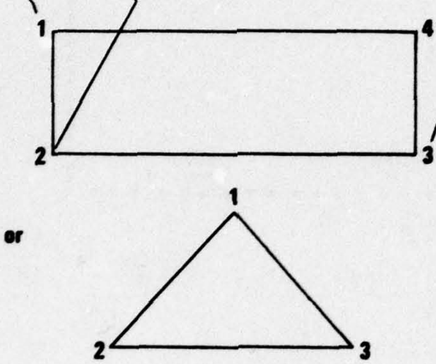


Figure 33. Vertices from Zone report.

```
PLAN VIEW OF ZONE HEAT TRANSFER SURFACES.
                                                                 +Y          N
MIN X =       0.                                                  1          1
MAX X =      12.00                                            -X--+--+X   W--+--E
MIN Y =       0.                                                  1          1
MAX Y =      25.00                                               -Y          S
```

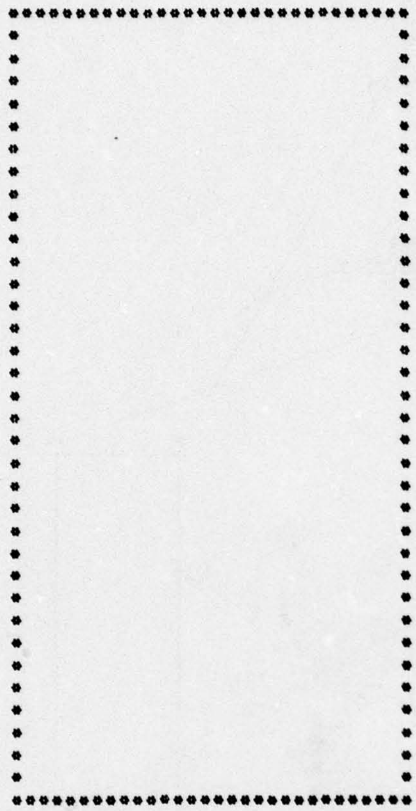


Figure 34. Sketch of zone from Zone report.

SHADE – This report causes the periodic printing (14 times per zone per 1-year simulation) of 24-hour values of sunlit area functions for all zone heat transfer surfaces. This report is useful for doing DESIGN DAY calculations to determine proper dimensions for overhangs and wings. It may also be useful to see if individual windows can be combined without changing solar gains. (See Figure 35).

CONTINUOUS – This report option causes daily totals of the zone loads report values to be printed in addition to the monthly and annual totals. One line is printed for each day of the simulation period for each zone. One page is printed per month of simulation with the usual monthly summaries. This report can be rather lengthy if several zones are being simulated. The column headings and meanings are the same as those used in the default loads summary report.

```
RESULTS OF SHADOWING CALCULATIONS

    SIN(DECL) = .3521   COS(DECL) = .9360   EQN OF TIME =-.1038

FORM OF DATA:  / COSINE OF INCIDENCE. SUNLIT FRACTION /

STANDARD TIME =  5:30
/ -.390.0.    / -.390.0.    / -.918.0.    /  .918.0.    /    /  .390.0.    / .078.1.000 / -.078.0.    /
STANDARD TIME =  6:30
/ -.237.0.    / -.237.0.    / -.934.0.    /  .934.0.    /    /  .237.0.    / .267.1.000 / -.267.0.    /
STANDARD TIME =  7:30
/ -.086.0.    / -.086.0.    / -.887.0.    /  .887.0.    /    /  .086.0.    / .454.1.000 / -.454.0.    /
STANDARD TIME =  8:30
/  .052. .436 /  .052. .374 / -.779.0.    /  .779.0.    /    / -.052.0.    / .625.1.000 / -.625.0.    /
STANDARD TIME =  9:30
/  .167. .325 /  .167. .156 / -.618.0.    /  .618.0.    /    / -.167.0.    / .768.1.000 / -.768.0.    /
STANDARD TIME = 10:30
/  .253. .226 /  .253. .024 / -.416.0.    /  .416.0.    /    / -.253.0.    / .874.1.000 / -.874.0.    /
STANDARD TIME = 11:30
/  .302. .098 /  .302.0.    / -.184.0.    /  .184.0.    /    / -.302.0.    / .935.1.000 / -.935.0.    /
STANDARD TIME = 12:30
/  .313. .031 /  .313.0.    /  .059.1.000 / -.059.0.    /    / -.313.0.    / .948.1.000 / -.948.0.    /
STANDARD TIME = 13:30
/  .283. .164 /  .283.0.    /  .299.1.000 / -.299.0.    /    / -.283.0.    / .911.1.000 / -.911.0.    /
STANDARD TIME = 14:30
/  .215. .275 /  .215. .077 /  .519.1.000 / -.519.0.    /    / -.215.0.    / .828.1.000 / -.828.0.    /
STANDARD TIME = 15:30
/  .114. .375 /  .114. .251 /  .703.1.000 / -.703.0.    /    / -.114.0.    / .702.1.000 / -.702.0.    /
STANDARD TIME = 16:30
/ -.013.0.    / -.013.0.    /  .839.1.000 / -.839.0.    /    /  .013.0.    / .545.1.000 / -.545.0.    /
STANDARD TIME = 17:30
/ -.158.0.    / -.158.0.    /  .918.1.000 / -.918.0.    /    /  .158.0.    / .365.1.000 / -.365.0.    /
STANDARD TIME = 18:30
/ -.311.0.    / -.311.0.    /  .934.1.000 / -.934.0.    /    /  .311.0.    / .175.1.000 / -.175.0.    /
```

DECL = solar declination
equation of time in hours

Sunlit fractions are reported for heat transfer surfaces only (no overhangs, etc.).

Figure 35. SHADE report.

```
SHADOWING COMBINATIONS FOR ZONE     1

GRSNR =    1     NGSS =  1     NBKS =  0     NSBS =  1
   GSSNR =       3
   SBSNR =       2

GRSNR =    4     NGSS =  0     NBKS =  0     NSBS =  0

GRSNR =    7     NGSS =  0     NBKS =  0     NSBS =  0
```

GRSNR = general receiving surface number
GSSNR = general shadowing surface number
SBSNR = sub-surface number

these refer to the surface numbers in the Surfaces of Zone report.

GRS are exterior walls, roofs, exposed floors
SBS are windows and doors
GSS are wings, overhangs, detached shadowing

NGSS = number of general shadowing surfaces
NBKS = not used
NSBS = number of sub-surfaces

Figure 35. (Cont'd).

5 FAN SYSTEM DESCRIPTION

Introduction

The fan system description begins with

BEGIN FAN SYSTEM DESCRIPTION;

and ends with

END FAN SYSTEM DESCRIPTION;

Just as each zone description begins with a number and title in the building description, each fan system description begins with a system identifier and ends with END SYSTEM;. For example,

```
BEGIN FAN SYSTEM DESCRIPTION;

        MULTIZONE SYSTEM 72 "MAIN FAN SYSTEM" SERVING ZONES 1,2,3,4;

        .
        .  ├ Description of fan system
        .

        END SYSTEM;

    .
    .  ├ Description of other fan systems
    .

END FAN SYSTEM DESCRIPTION;
```

Between the specification of the system, number, title, type, and zones being served and the END SYSTEM; statement, there are six blocks of data which are used to describe the system:

FOR ZONE usn:

Data on each zone such as air flow rate and reheat capacity.

END ZONE;

OTHER SYSTEM PARAMETERS:

Data on other system variables such as hot deck and cold deck temperatures and control strategies, outside air volumes and schedules, and fan pressure and efficiency.

END OTHER SYSTEM PARAMETERS;

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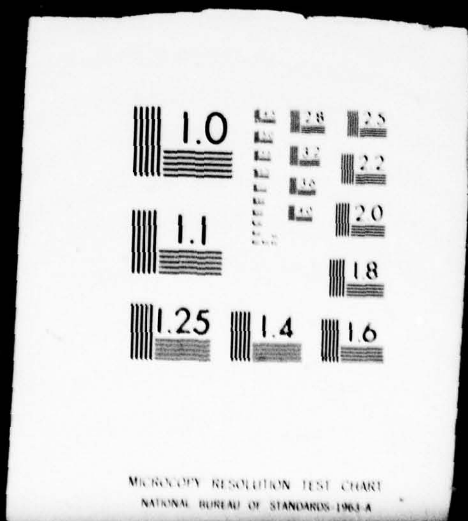

COOLING COIL DESIGN PARAMETERS:

Data on a single coil operating point such as entering and leaving water, air temperatures, and flow rates.

END COOLING COIL DESIGN PARAMETERS;

DX CONDENSING UNIT PARAMETERS:

Performance parameters used to simulate condensing units.

END DX CONDENSING UNIT PARAMETERS;

HEAT RECOVERY PARAMETERS:

Air-to-air heat recovery parameters.

END HEAT RECOVERY PARAMETERS;

EQUIPMENT SCHEDULES:

Specifies when fans and coils are allowed to operate (daily and seasonally).

END EQUIPMENT SCHEDULES;

The user can terminate any of these descriptions with either END; or the full syntax as listed above.

With the exception of the zone data block, data for all parameters in all other input data blocks have default values which may or may not be adjusted at the user's discretion. Only in rare cases, however, will all defaults be appropriate for the simulation of a particular fan system.

System Identifier

The specification of system type, number, title, and zones must be input after BEGIN FAN SYSTEM DESCRIPTION:. For example:

Typical required punctuation

<u>MULTIZONE</u> SYSTEM <u>72</u> <u>"MAIN FAN SYSTEM"</u> SERVING ZONES <u>1</u>, <u>2</u>, <u>3</u>, <u>4</u>;

System type

System number

System title in quotes, up to 40 characters

Zones served by the system

The system types can be any one of the following (see Appendix F for fan system diagrams):

TERMINAL REHEAT	TWO PIPE FAN COIL	MULTIZONE
VARIABLE VOLUME	FOUR PIPE FAN COIL	SUBZONE REHEAT
UNIT VENTILATOR	DUAL DUCT VARIABLE VOLUME	DX PACKAGED UNIT
THREE DECK MULTIZONE	SINGLE ZONE DRAW THROUGH	

Every system must be assigned a different number; the system title may contain up to 40 characters and must be inclosed in quotes.

The last line of each system (following the description of zone data or defaults which are to be overridden) is:

END SYSTEM;

Subsequent systems are described in a similar fashion.

Zone Data Block

Data block descriptions can be placed anywhere in the fan system description. The only *required* data block is the zone data block; as a minimum, this block must indicate the supply air volume to each zone on the fan system being simulated. For example:

```
FOR ZONE 1:

SUPPLY AIR VOLUME=500;

END ZONE;
```

Since the syntax can appear anywhere on the line, the above example could also be written as:

```
FOR ZONE 1:SUPPLY AIR VOLUME=500;END ZONE;
```

The following example shows format and default values for a zone data block. Up to 20 distinct zones may be specified for each system (one zone data block per zone).

Begins zone data block for zone usn1.

```
FOR ZONE usn1:

   SUPPLY AIR VOLUME=usn2;
   MINIMUM AIR FRACTION=0.1;
   EXHAUST AIR VOLUME=0.0;
   REHEAT CAPACITY=0.0;
   REHEAT ENERGY SUPPLY=HOT WATER;
   BASEBOARD HEAT CAPACITY=0.0;
   BASEBOARD HEAT ENERGY SUPPLY=HOT WATER;
   ZONE MULTIPLIER=1.0;

END ZONE;
```

Ends zone data block

SUPPLY AIR VOLUME is the airflow rate of the zone under peak conditions in ft^3/min (m^3/s).

MINIMUM AIR FRACTION applies only to variable volume systems and is the minimum fraction of the zone's design supply volume which will be delivered to the space any time the fan system is running. The minimum air fraction specified in the zone block takes precedence over any minimum air fraction later specified in the **OTHER SYSTEM PARAMETERS** block. If not specified, the minimum air fraction defaults to the minimum air fraction specified in **OTHER SYSTEM PARAMETERS.**

EXHAUST AIR VOLUME is the amount of air which will be removed from the zone any time the fan system is in operation (ft^3/min [m^3/s]) and which will be exhausted directly (without heat recovery). BLAST will always verify that the supply air volume, whether in a fixed or variable volume system, is equal to or greater than the exhaust air volume.

REHEAT CAPACITY is input in kBtu/hr (kW) and applies only to terminal reheat systems, variable volume system with reheat, subzone reheat systems, and unit ventilator systems. The default capacity is 0.

REHEAT ENERGY SUPPLY is one of **HOT WATER, STEAM, ELECTRIC,** or **GAS. HOT WATER** is the default.

BASEBOARD HEAT CAPACITY, specified in kBtu/hr (kW), is thermostatically controlled baseboard heat. It can *only* be used with single duct VAV systems. It differs from reheat in that it does not require air flow through the fan system to operate at full capacity. Both **BASEBOARD HEAT CAPACITY** *and* **REHEAT CAPACITY** cannot be specified for the same zone.

BASEBOARD HEAT ENERGY SUPPLY is exactly the same as **REHEAT ENERGY SUPPLY.**

ZONE MULTIPLIER is used to simulate identical or nearly identical spaces. It would be pointless to calculate loads and perform simulations for two identical zones (same orientation, dimensions, construction, schedules, etc.), since if these zones are truly identical, the hourly load profiles and impact on the air distribution system will also be identical. The **ZONE MULTIPLIER** avoids the need for redundant load calculation by accounting for the zone's impact on electric power demand, coil energy demands, and fan energy demand N times, where N is the zone multiplier. In practice, zones which are nearly identical (very similar) can be treated as identical to simplify input and avoid calculation expense.

Other System Parameters

Program defaults for air distribution system variables of interest to the designer can be overridden. Many of these variables are changed by using the **OTHER SYSTEM PARAMETERS** data block. For example, users can alter the hot and cold deck control strategy of a multizone system by specifying:

Begins input data block

```
OTHER SYSTEM PARAMETERS:
    COLD DECK CONTROL=ZONE CONTROLLED;        New values for parameters
    HOT DECK TEMPERATURE=12Ø;                 Names of parameters
END OTHER SYSTEM PARAMETERS;
```

Ends input data block, (END is equivalent)

Table 4 lists all **OTHER SYSTEM PARAMETERS** and their respective default values. Table 5 lists the fan system types and indicates which of the other system parameters are relevant to the simulation of each type. Other details are in Appendix F.

The entire block of entries for **OTHER SYSTEM PARAMETERS** can be placed anywhere in the system descriptions as long as it follows the system identifier and lies outside other data blocks. Specifying **OTHER SYSTEM PARAMETERS** *only* affects the system being described; it has no effect on subsequent fan systems which may be described for simulation in the same BLAST run. Changes in the default values, if desired, must be repeated system by system.

Table 4
OTHER SYSTEM PARAMETERS and Their Defaults in English Units

```
OTHER SYSTEM PARAMETERS
  SUPPLY FAN PRESSURE = 2.5;
  EXHAUST FAN PRESSURE = 1;
  RETURN FAN PRESSURE = 0.0;
  SUPPLY FAN EFFICIENCY = 0.7;
  EXHAUST FAN EFFICIENCY = 0.7;
  RETURN FAN EFFICIENCY = 0.7;

    COLD DECK CONTROL = FIXED SET POINT;  (default)
                 (or) = OUTSIDE AIR CONTROLLED;
                 (or) = ZONE CONTROLLED;

    COLD DECK TEMPERATURE = 55;
    COLD DECK THROTTLING RANGE = 7.2;
    COLD DECK CONTROL SCHEDULE = (55 AT 90, 65 AT 70);
                          (or) = (32 AT 32, 212 AT 212);   (if COLD DECK CONTROL =
                                                            ZONE CONTROLLED;)

    HEATING COIL CAPACITY = 3412000;
                     (in kBtu/hr [or kW])

    HEATING COIL ENERGY SUPPLY = HOT WATER;  (default)
                          (or) = GAS;
                          (or) = ELECTRIC;
                          (or) = STEAM;

    HOT DECK CONTROL = FIXED SET POINT;  (default)
                (or) = OUTSIDE AIR CONTROLLED;
                (or) = ZONE CONTROLLED;
    HOT DECK TEMPERATURE = 140;
    HOT DECK CONTROL SCHEDULE = (140 AT 0, 70 AT 70);
                         (or) = (32 AT 32, 212 AT 212);    (if HOT DECK CONTROL = ZONE
                                                            CONTROLLED;)
    HOT DECK THROTTLING RANGE = 7.2;
    MIXED AIR CONTROL = FIXED PERCENT;  (default)
                 (or) = FIXED AMOUNT;
                 (or) = TEMPERATURE ECONOMY CYCLE;
                 (or) = RETURN AIR ECONOMY CYCLE;
                 (or) = ENTHALPY ECONOMY CYCLE;
```

Table 4 (cont'd)

```
DESIRED MIXED AIR TEMPERATURE = COLD DECK TEMPERATURE;  (default)
                              (or) = 50;  (a fixed temperature)

OUTSIDE AIR VOLUME = 0.0;
WEEKDAY MINIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - .15);
                                (or) = (00 TO 24 - 1);      (if MIXED AIR CONTROL =
                                                             FIXED AMOUNT;)
WEEKEND MINIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - .05);
                                (or) = (00 TO 24 - 1);      (if MIXED AIR CONTROL =
                                                             FIXED AMOUNT;)
WEEKDAY MAXIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - 1);

WEEKEND MAXIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - 1);

PREHEAT COIL LOCTION = NONE;  (default)
                (or) = OUTSIDE AIR DUCT;
                (or) = MIXED AIR DUCT;

PREHEAT TEMPERATURE = 46.4;
PREHEAT COIL CAPACITY = 0.0;
GAS BURNER EFFICIENCY = 0.8;

PREHEAT ENERGY SUPPLY = HOT WATER;  (default)
                 (or) = GAS;
                 (or) = ELECTRIC;
                 (or) = STEAM;

VAV MINIMUM AIR FRACTION = 0.1;
VAV VOLUME CONTROL TYPE = INLET VANES;  (default)   (Specify either VAV CONTROL TYPE
                   (or) = VARIABLE FAN SPEED;       or FAN POWER COEFFICIENTS)
                   (or) = DISCHARGE DAMPERS;

HUMIDIFIER TYPE = NONE;  (default)
           (or) = STEAM;
           (or) = HOT WATER;
           (or) = ELECTRIC;

HUMIDISTAT LOCATION = (  user specified zone number  );   (Humidity is added only when cooling
                                                          coil load is zero, i.e., during heating)
HUMIDISTAT SET POINT = 50;      (percent)
FAN POWER COEFFICIENTS = ( 0, 0, 0, 0, 0 );    (If FAN POWER COEFFICIENTS are specified, do not
END OTHER SYSTEM PARAMETERS;                   specify VAV VOLUME CONTROL TYPE)
```

Table 5
Other System Parameters Applicability

Other System Parameters Applicability

● INDICATES PARAMETER MAY AFFECT SYSTEM

	MULTIZONE	DUAL DUCT (2)	DUAL DUCT VARIABLE VOLUME	THREE DECK MULTIZONE	VARIABLE VOLUME	TERMINAL REHEAT (1)	SUBZONE REHEAT (1)	TWO PIPE FAN COIL (1)	FOUR PIPE FAN COIL (1)	SINGLE ZONE DRAW THRU	DX PACKAGED UNIT	UNIT VENTILATOR
SUPPLY FAN PRESSURE & EFFICIENCY	●	●	●	●	●	●	●	●	●	●	●	●
RETURN FAN PRESSURE & EFFICIENCY	●	●	●	●	●	●	●			●	●	●
EXHAUST FAN PRESSURE & EFFICIENCY	●	●	●	●	●	●	●	●	●	●		●
COLD DECK CONTROL/TEMPERATURE	●	●	●	●	●	●	●	●	●	●		
COLD DECK THROTTLING RANGE	●	●	●	●	●	●	●			●		
COLD DECK CONTROL SCHEDULE	●	●	●	●	●	●	●			●		
HEATING COIL ENERGY/CAPACITY	●	●	●	●				●	●	●	●	●
HOT DECK CONTROL/TEMPERATURE	●	●	●	●	●	●	●	●	●	●	●	●
HOT DECK THROTTLING RANGE	●	●	●	●						●		●
HOT DECK CONTROL SCHEDULE	●	●	●	●	●	●	●	●	●	●	●	●
MIXED AIR CONTROL	●	●	●	●	●	●	●			●	●	●
DESIRED MIXED AIR TEMPERATURE	●	●	●	●	●	●	●			●	●	●
OUTSIDE AIR VOLUME	●	●	●	●	●	●	●			●	●	●
WEEKDAY MINIMUM OUTSIDE AIR SCHEDULE	●	●	●	●	●	●	●	●	●	●	●	●
WEEKDAY MAXIMUM OUTSIDE AIR SCHEDULE	●	●	●	●	●	●	●			●	●	●
WEEKEND MINIMUM OUTSIDE AIR SCHEDULE	●	●	●	●	●	●	●	●	●	●	●	●
WEEKEND MAXIMUM OUTSIDE AIR SCHEDULE	●	●	●	●	●	●	●			●	●	●
PREHEAT COIL LOCATION	●	●	●	●	●	●	●			●		●
PREHEAT AT TEMPERATURE	●	●	●	●	●	●	●			●		●
PREHEAT ENERGY/CAPACITY	●	●	●	●	●	●	●			●		●
GAS BURNER EFFICIENCY	●	●	●	●	●	●	●		●	●	●	●
VAV MINIMUM AIR FRACTION			●		●							
VAV VOLUME CONTROL			●		●							
FAN POWER COEFFICIENTS			●		●							
HUMIDIFIER TYPE	●	●	●	●	●	●	●			●		●
HUMIDISTAT LOCATION	●	●	●	●	●	●	●			●		●
HUMIDISTAT SET POINT	●	●	●	●	●	●	●			●		●

NOTES:

1. HOT DECK TEMPERATURE SETS UPPER LIMIT ON REHEAT OR HEATING COIL TEMP.
2. DUAL DUCT IS THE SAME AS MULTIZONE IN BLAST; MULTIZONE IS THE RECONIZED NAME.

Cooling Coil Design Parameters

The **COOLING COIL DESIGN PARAMETERS** input data block allows the user to specify a cooling coil of her/his choice by inputting data for one coil operating point. Table 6 shows the data necessary for each of the four types of coils BLAST can simulate.

The applicable cooling coil design variables and defaults change with the type of coil (and in some cases, with the type of system) specified by the user. Variables and defaults must be input using some of the following syntax:

```
COOLING COIL DESIGN PARAMETERS:                     <- Begins input data block
  COIL TYPE = CHILLED WATER;

        (or) = DIRECT EXPANSION;
        (or) = DX;

  ENTERING REFRIGERANT TEMPERATURE = ;   |
  LEAVING REFRIGERANT TEMPERATURE = ;    |
  ENTERING WATER TEMPERATURE = ;         |
  ENTERING AIR DRY BULB TEMPERATURE = ;  |-- All temperatures are in °F (or °C)
  ENTERING AIR WET BULB TEMPERATURE = ;  |
  LEAVING WATER TEMPERATURE = ;          |
  LEAVING AIR DRY BULB TEMPERATURE = ;   |
  LEAVING AIR WET BULB TEMPERATURE = ;   |
  TOTAL COOLING LOAD = ;  |-- Capacity in 100 Btu/hr (kW)
  NUMBER OF TUBE CIRCUITS = ;
  WATER VELOCITY = ;             |
  WATER VOLUME FLOW RATE = ;     |-- Velocities are in ft/min (or m/sec)
  AIR FACE VELOCITY = ;          |   Flow rates are ft³/min (or m³/sec)
  AIR VOLUME FLOW RATE = ;       |   1 GPM = .1338 ft³/min
  BAROMETRIC PRESSURE = ;  |-- In in. H2O (407 in. H2O = 1 atmosphere)
  DXCOIL1( , , );  |
  DXCOIL2( , , );  |-- Package DX coil parameters (see Appendix F)
  DXCOIL3( , , );  |
END COOLING COIL DESIGN PARAMETERS;                 <- Ends input data block (END; is equivalent)
```

The following sections are sample descriptions of each of the four major coil types. Each sample includes default values.

Packaged DX Coil

```
COOLING COIL DESIGN PARAMETERS:

    DXCOIL1 (4589.14, 1.63, -.02011);
    DXCOIL2 (-25.342, .02492, .00461);
    DXCOIL3 (.01715, -.000051, -1.715E-8);

END COOLING COIL DESIGN PARAMETERS;
```

(If and only if a user specifies a DX PACKAGED UNIT as the system type, a special packaged DX coil model is used and only these COOLING COIL DESIGN PARAMETERS apply [see Appendix F for details]. The COIL TYPE is DIRECT EXPANSION regardless of user input.)

Table 6
Data Necessary for Cooling Coil Design Parameters

Cooling Coil Design Parameters Applicability

● INDICATES PARAMETER AFFECTS SYSTEM

	PACKAGED DX COILS	DIRECT EXPANSION COILS	WATER COILS IN FAN COIL UNITS	ALL OTHER CILLED WATER COILS
COIL TYPE		●		●
AIR VOLUME FLOW RATE		●	●	●
BAROMETRIC PRESSURE		●	●	●
AIR FACE VELOCITY		●		●
ENTERING AIR DRY BULB TEMPERATURE		●	●	●
ENTERING AIR WET BULB TEMPERATURE		●	●	●
LEAVING AIR DRY BULB TEMPERATURE		●	●	●
LEAVING AIR WET BULB TEMPERATURE		●		●
ENTERING WATER TEMPERATURE			●	●
LEAVING WATER TEMPERATURE			●	●
WATER VOLUME FLOW RATE			●	●
WATER VELOCITY				●
ENTERING REFRIGERANT TEMPERATURE		●		
LEAVING REFRIGERANT TEMPERATURE		●		
TOTAL COOLING LOAD		●		
NUMBER OF TUBE CIRCUITS		●		
DXCOIL1 } PERFORMANCE COEFFICIENTS FOR PACKAGE DX UNITS	●			
DXCOIL2 } PERFORMANCE COEFFICIENTS FOR PACKAGE DX UNITS	●			
DXCOIL3 } PERFORMANCE COEFFICIENTS FOR PACKAGE DX UNITS	●			

Water Coils in Fan Coil Units

```
COOLING COIL DESIGN PARAMETERS:

    AIR VOLUME FLOW RATE = 6ØØ;
    BAROMETRIC PRESSURE = 4Ø6.8;
    ENTERING AIR DRY BULB TEMPERATURE = 8Ø;
    ENTERING AIR WET BULB TEMPERATURE = 67;
    LEAVING AIR DRY BULB TEMPERATURE = 6Ø.4;
    ENTERING WATER TEMPERATURE = 45;
    LEAVING WATER TEMPERATURE = 54.6;
    WATER VOLUME FLOW RATE = .5348;

END COOLING COIL DESIGN PARAMETERS;
```

(Defaults and the only applicable COOLING COIL DESIGN PARAMETERS when a user selects a two- or four-pipe fan coil system. Regardless of what the user inputs, COIL TYPE for fan coil systems is CHILLED WATER.)

Direct Expansion Coils

```
COOLING COIL DESIGN PARAMETERS:

    COIL TYPE = DX;                          (Direct expansion cooling coils can be selected for all
          (or)  = DIRECT EXPANSION;          system types except fan coils by overriding the default
                                             coil type [CHILLED WATER])
    AIR VOLUME FLOW RATE = 12000;  (in ft³/m [or m³/s])
    BAROMETRIC PRESSURE = 405;
    AIR FACE VELOCITY = 600;
    ENTERING AIR DRY BULB TEMPERATURE = 80;
    ENTERING AIR WET BULB TEMPERATURE = 67;
    LEAVING AIR DRY BULB TEMPERATURE = 55;
    LEAVING AIR WET BULB TEMPERATURE = 44;
    ENTERING REFRIGERANT TEMPERATURE = 40;
    LEAVING REFRIGERANT TEMPERATURE = 40;
    TOTAL COOLING LOAD = 487.33;  (in kBtu/hr [or kW] –represents total coil capacity)
    NUMBER OF TUBE CIRCUITS = 20;

END COOLING COIL DESIGN PARAMETERS;
```

All Other Chilled Water Coils

```
COOLING COIL DESIGN PARAMETERS:

    COIL TYPE = CHILLED WATER;           (Default COIL TYPE for all systems except DX PACKAGED
                                         UNITS is CHILLED WATER)
    AIR VOLUME FLOW RATE =    ; (sum of zone air flow rates)        (Defaults correspond to a
    BAROMETRIC PRESSURE = 407;                                      typical four row coil. This is
    AIR FACE VELOCITY = 490;                                        the only coil type which is
    ENTERING AIR DRY BULB TEMPERATURE = 85;                         automatically scaled by
    ENTERING AIR WET BULB TEMPERATURE = 64;                         BLAST based on total system
    LEAVING AIR DRY BULB TEMPERATURE = 55;                          air volume flow rate.)
    LEAVING AIR WET BULB TEMPETATURE = 52.7;
    ENTERING WATER TEMPERATURE = 45;
    LEAVING WATER TEMPERATURE = 55;
    WATER VOLUME FLOW RATE =    ;         (.0089 times air flow rate)
    WATER VELOCITY = 275;

END COOLING COIL DESIGN PARAMETERS;
```

Except for DX PACKAGED UNITS and fan coil units, the COOLING COIL PARAMETERS (user specified or default) are used to compute an equivalent heat transfer area and overall heat transfer coefficient for the coil. These values become the basis for a precise simulation of coil performance under actual hourly entering and leaving air conditions and flow rates encountered during the simulation period.

Direct expansion coils in DX PACKAGED UNITS and chilled water coils in fan coil units are modeled somewhat differently (and the input is somewhat different) from their counterparts in

other types of systems because (1) catalog data for these coils are usually presented in a different form and (2) the air temperature leaving the coil is not usually controlled. Appendix F discusses packaged DX coils and fan coil unit modeling in more detail.

Whenever a DX or packaged DX coil is specified, a DX CONDENSING UNIT *to serve the coil is automatically simulated (one for each fan system served by a DX coil; see* DX CONDENSING UNIT PARAMETERS *and Appendix F).*

Air-to-Air Heat Recovery Parameters

For air-to-air heat recovery (i.e., heat wheel or heat pipe), the parameter block below is used for all fan systems except DX PACKAGED UNIT, TWO PIPE FAN COIL, and FOUR PIPE FAN COIL

```
HEAT RECOVERY PARAMETERS:

    HTREC1 (0.85, 0.0, 0.0); |———— (Corresponds to an 85 percent efficient heat
    HTREC2 (0.0, 0.0, 0.0);         recovery device consuming no power)
    HTREC3 (0.0, 0.0, 0.0);
    HTPWR  (0.0, 0.0, 0.0);
    HEAT RECOVERY CAPACITY = 3412000; (in kBtu/hr [or kW])

END HEAT RECOVERY PARAMETERS;
```

The three HTPWR coefficients are used to determine the energy consumption of the heat recovery device:

$$\text{Power Consumed} = \text{HTPWR}(1) + \text{HTPWR}(2) * \text{QREC} + \text{HTPWR}(3) * \text{QREC}^2 \qquad \text{[Eq 5]}$$

where: QREC is the amount of heat recovered during the current hour.

The HTREC1, HTREC2, and HTREC3 coefficients are used to determine the effectiveness of the heat recovery device.

$$\begin{aligned}\text{Heat Recovery Effectiveness} = {} & \text{HTREC1(1)} + \text{HTREC1(2)} * \text{MAXFLOW} + \text{HTREC1(3)} \\ & * \text{MAXFLOW}^2 + \text{HTREC2(1)} * \text{RATFLOW} + \text{HTREC2(2)} \\ & * \text{MAXFLOW} * \text{RATFLOW} + \text{HTREC2(3)} * \text{MAXFLOW}^2 \\ & * \text{RATFLOW} + \text{HTREC3(1)} * \text{RATFLOW}^2 + \text{HTREC3(2)} \\ & * \text{MAXFLOW} * \text{RATFLOW}^2 + \text{HTREC3(3)} * \text{MAXFLOW}^2 \\ & * \text{RATFLOW}^2\end{aligned}$$

where: MAXFLOW = larger of relief air mass flow and outside air mass flow for the current hour

RATFLOW = MAXFLOW divided by smaller of relief air mass flow or outside air mass flow for the current hour.

Users are advised to find a good "canned" curve-fitting program on the computer they are using if a constant effective heat exchange is not a sufficiently accurate approximation for the system being simulated and HTREC1, HTREC2, and HTREC3 coefficients must be determined.

Equipment Schedules

Equipment schedules are specified using all or part of the input data block shown below:

Begins input data block.

```
EQUIPMENT SCHEDULES:

    SYSTEM OPERATION=CONTINUOUS;      (default value)
                (or)=INTERMITTENT;
    WEEKDAY SYSTEM SCHEDULE=(ØØ TO 18-ON, 18 to Ø8-OFF);
    WEEKEND SYSTEM SCHEDULE=(ØØ TO 24-OFF);          (state weekday and weekend
    WEEKDAY PREHEAT SCHEDULE = (ØØ TO 24-ON);         separately even if identical)
    WEEKEND PREHEAT SCHEDULE = (ØØ TO 24-ON);
    WEEKDAY HEATING SCHEDULE = (ØØ TO 24-ON);
    WEEKEND HEATING SCHEDULE = (ØØ TO 24-ON);
    WEEKDAY COOLING SCHEDULE = (ØØ TO 24-ON);
    WEEKDAY COOLING SCHEDULE = (ØØ TO 24-ON);
    WEEKDAY HEAT RECOVERY SCHEDULE = (ØØ TO 24-ON);
    WEEKEND HEAT RECOVERY SCHEDULE = (ØØ TO 24-ON);
    HEAT RECOVERY ON FROM ØØ JAN THRU ØØ JAN:    (i.e., heat recovery is always off)
    PREHEAT CAPACITY ON FROM Ø1 JAN THRU 31 DEC;
    HEATING CAPACITY ON FROM Ø1 JAN THRU 31 DEC;
    COOLING CAPACITY ON FROM Ø1 JAN THRU 31 DEC;

END EQUIPMENT SCHEDULES;
```

Ends input data block (END; is equivalent)

Equipment schedule parameters determine when the air-handling system will operate. If system operation is specified as CONTINUOUS, the fan will operate throughout the simulation. Otherwise, its operation will be determined by the system schedule and the zone loads; i.e., the system will be on throughout the scheduled "on" period and off during the scheduled "off" period. However, the system will run even during the "off" period if there is a zone demand during any one hour. This schedule should, therefore, correspond to the control schedule specified in the zone load calculation phase. The fan operating mode and schedule can greatly affect the amount of energy required to heat and cool outside air. The preheat, heating, and cooling capacity schedules indicate the daily and seasonal period when these coils are supplied with energy. If chillers are shut off at night and on weekends, the user should specify a cooling coil schedule like the following example:

```
•
•
WEEKDAY COOLING SCHEDULE = (Ø7 TO 18-ON, 18 to Ø7-OFF);
WEEKEND COOLING SCHEDULE = (ØØ TO 24-OFF);
```

In this example, no cooling energy will be used at night or on weekends even if the fan runs continuously or comes on at night because a heating (or cooling) load occurs.

For TWO PIPE FAN COIL systems, the user *must* override the seasonal heating and cooling availability schedules with schedules that do not overlap. This is because two pipe fan coil units cannot simultaneously heat and cool.

DX Condensing Unit Parameters

If a DX Packaged Unit is selected or if a DX coil is used in one of the other system types, a special group of parameters is involved. For these parameters, the default values supplied by the program in absence of user input and the format of the statements which allow the user to override the defaults are:

Begin input data block.

```
DX CONDENSING UNIT PARAMETERS:

    RCAVCD (.0080, -.007067, .0000185);
    RPWRCD (.1456, .9554, -.10476);
    ADJECD (.2984, .1334, 34.603);
    DESIGN SATURATED SUCTION TEMPERATURE = 40;
    DESIGN SATURATED CONDENSING TEMP = 122;
    MINIMUM SATURATED CONDENSING TEMP = 88;
    UNLOADER THROTTLING RANGE = 4;
    CONDENSER UA = 27.43;
    SCT TEMPERATURE RISE = 2.53;
    DESIGN FULL LOAD POWER RATIO = 3.26;
    DX CONDENSING UNIT CAPACITY = 487.4;

END DX CONDENSING UNIT PARAMETERS;
```

Ends input data block (END; is equivalent)

Appendix F defines the various parameters and describes how to calculate the necessary coefficients. These parameters and user-specified DX coil capacities are used to model compressor-condenser performance of an air cooled condensing unit.

Reports

BLAST will print as many as four summary reports directly related to the results of an air-handling system simulation.

AIR HANDLING SYSTEM ENERGY USE SUMMARY lists the annual and monthly total and peak demand for building and fan system consumption of electricity, gas, steam, hot water, and chilled water. This report is automatically produced any time a system is simulated. Figure 36 shows a sample of this report.

AIR HANDLING SYSTEM LOADS NOT MET SUMMARY lists the excess of demand over capacity (where all demand is met, a zero or "NO UNMET LOADS FOR THIS ZONE" is printed). Unmet zone loads are caused by insufficient air flow or a deck temperature specified too low or high to deliver air hot or cold enough to meet all loads. This report is automatically produced any time a system is simulated. A sample is shown in Figure 37.

AIR HANDLING SYSTEM COMPONENT LOADS SUMMARY is produced only if specifically requested under the RUN CONTROL (COIL LOADS report). It lists energy consumption and use statistics for all coils, humidifiers, and baseboard heat (see Figure 38).

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0 28 MAR 79 18.17.13

AIR HANDLING SYSTEM ENERGY USE SUMMARY

SYSTEM NUMBER = 72 SYSTEM LOCATION = 13983 SIMULATION PERIOD = 1/ 1/1968 - 12/31/1968

ELECTRICITY

MONTH	BUILDING LIGHTS		FANS		HEATING		TOTAL USE	
	CONSUMPTION (BTU)	PEAK DEMAND (BTU/HR)	CONSUMPTION (BTU)	PEAK DEMAND (BTU/HR)	CONSUMPTION (BTU)	PEAK DEMAND (BTU/HR)	CONSUMPTION (BTU)	PEAK DEMAND (BTU/HR)
JAN	1.764E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.397E+06	1.034E+04
FEB	1.610E+06	6.800E+03	2.463E+06	3.538E+03	0.	0.	4.073E+06	1.034E+04
MAR	1.695E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.328E+06	1.034E+04
APR	1.756E+06	6.800E+03	2.548E+06	3.538E+03	0.	0.	4.303E+06	1.034E+04
MAY	1.764E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.397E+06	1.034E+04
JUN	1.618E+06	6.800E+03	2.548E+06	3.538E+03	0.	0.	4.166E+06	1.034E+04
JUL	1.764E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.397E+06	1.034E+04
AUG	1.764E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.397E+06	1.034E+04
SEP	1.618E+06	6.800E+03	2.548E+06	3.538E+03	0.	0.	4.166E+06	1.034E+04
OCT	1.695E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.328E+06	1.034E+04
NOV	1.618E+06	6.800E+03	2.548E+06	3.538E+03	0.	0.	4.166E+06	1.034E+04
DEC	1.676E+06	6.800E+03	2.633E+06	3.538E+03	0.	0.	4.309E+06	1.034E+04
	----------	----------	----------	----------	----------	----------	----------	----------
ANN	2.034E+07	6.800E+03	3.108E+07	3.538E+03	0.	0.	5.143E+07	1.034E+04

Figure 36. Air Handling System Energy Use Summary.

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MONTH	GAS TOTAL USE CONSUMPTION (BTU)	GAS TOTAL USE PEAK DEMAND (BTU/HR)	STEAM TOTAL USE CONSUMPTION (BTU)	STEAM TOTAL USE PEAK DEMAND (BTU/HR)	HOT WATER TOTAL USE CONSUMPTION (BTU)	HOT WATER TOTAL USE PEAK DEMAND (BTU/HR)	CHILLED WATER TOTAL USE CONSUMPTION (BTU)	CHILLED WATER TOTAL USE PEAK DEMAND (BTU/HR)
JAN	0.	0.	0.	0.	3.241E+07	8.788E+04	1.393E+07	3.462E+04
FEB	0.	0.	0.	0.	2.906E+07	8.222E+04	1.311E+07	3.200E+04
MAR	0.	0.	0.	0.	2.597E+07	7.225E+04	1.875E+07	4.171E+04
APR	0.	0.	0.	0.	2.366E+07	6.371E+04	2.132E+07	4.160E+04
MAY	0.	0.	0.	0.	2.452E+07	5.397E+04	2.475E+07	4.602E+04
JUN	0.	0.	0.	0.	2.613E+07	4.401E+04	3.029E+07	5.412E+04
JUL	0.	0.	0.	0.	2.706E+07	4.380E+04	3.222E+07	5.471E+04
AUG	0.	0.	0.	0.	2.668E+07	4.254E+04	3.188E+07	5.631E+04
SEP	0.	0.	0.	0.	2.525E+07	4.437E+04	2.676E+07	4.490E+04
OCT	0.	0.	0.	0.	2.417E+07	6.406E+04	2.247E+07	4.442E+04
NOV	0.	0.	0.	0.	2.546E+07	7.166E+04	1.645E+07	4.084E+04
DEC	0.	0.	0.	0.	3.086E+07	9.379E+04	1.423E+07	3.376E+04
	----------	----------	----------	----------	----------	----------	----------	----------
ANN	0.	0.	0.	0.	3.212E+08	9.379E+04	2.662E+08	5.631E+04

Figure 36. (cont'd)

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0 28 MAR 79 18.17.13

A I R H A N D L I N G S Y S T E M L O A D S N O T M E T S U M M A R Y

SYSTEM NUMBER= 72 SYSTEM LOCATION = 13983 SIMULATION PERIOD = 1/ 1/1968 - 12/31/1968

	HEATING			COOLING		
MONTH	LOAD NOT MET (BTU)	PEAK NOT MET (BTU/HR)	HOURS NOT MET (HOURS)	LOAD NOT MET (BTU)	PEAK NOT MET (BTU/HR)	HOURS NOT MET (HOURS)
ZONE 1						
JAN	0.	0.	0.	0.	0.	0.
FEB	0.	0.	0.	0.	0.	0.
MAR	0.	0.	0.	0.	0.	0.
APR	0.	0.	0.	0.	0.	0.
MAY	0.	0.	0.	0.	0.	0.
JUN	0.	0.	0.	0.	0.	0.
JUL	0.	0.	0.	0.	0.	0.
AUG	0.	0.	0.	0.	0.	0.
SEP	0.	0.	0.	0.	0.	0.
OCT	0.	0.	0.	0.	0.	0.
NOV	0.	0.	0.	0.	0.	0.
DEC	0.	0.	0.	2.209E+05	9.646E+03	2.400E+01
ANN	0.	0.	0.	2.209E+05	9.646E+03	2.400E+01

ZONE 2

NO UNMET LOADS FOR THIS ZONE

ZONE 3

NO UNMET LOADS FOR THIS ZONE

ZONE 4

NO UNMET LOADS FOR THIS ZONE

Figure 37. Air Handling System Loads Not Met Summary.

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0 28 MAR 79 18.17.13

A I R H A N D L I N G S Y S T E M C O M P O N E N T L O A D S U M M A R Y

SYSTEM NUMBER= 72 SYSTEM LOCATION = 13983 SIMULATION PERIOD = 1/ 1/1968 - 12/31/1968

	MONTH	CONSUMPTION (BTU)	PEAK DEMAND (BTU/HR)	HRS CNSMPTN (HOURS)	PK CAP EXCD (BTU/HR)	HRS CAP EXCD (HOURS)
HEATING COIL LOADS						
	JAN	3.241E+07	8.788E+04	7.440E+02	0.	0.
	FEB	2.906E+07	8.222E+04	6.960E+02	0.	0.
	MAR	2.597E+07	7.225E+04	7.440E+02	0.	0.
	APR	2.366E+07	6.371E+04	7.200E+02	0.	0.
	MAY	2.452E+07	5.397E+04	7.440E+02	0.	0.
	JUN	2.613E+07	4.401E+04	7.200E+02	0.	0.
	JUL	2.706E+07	4.380E+04	7.440E+02	0.	0.
	AUG	2.668E+07	4.254E+04	7.440E+02	0.	0.
	SEP	2.525E+07	4.437E+04	7.200E+02	0.	0.
	OCT	2.417E+07	6.406E+04	7.440E+02	0.	0.
	NOV	2.546E+07	7.166E+04	7.200E+02	0.	0.
	DEC	3.086E+07	9.379E+04	7.440E+02	0.	0.
	ANN	3.212E+08	9.379E+04	8.784E+03	0.	0.
COOLING COIL LOADS						
	JAN	1.393E+07	3.462E+04	7.440E+02	0.	0.
	FEB	1.311E+07	3.200E+04	6.960E+02	0.	0.
	MAR	1.875E+07	4.171E+04	7.440E+02	0.	0.
	APR	2.132E+07	4.160E+04	7.200E+02	0.	0.
	MAY	2.475E+07	4.602E+04	7.440E+02	0.	0.
	JUN	3.029E+07	5.412E+04	7.200E+02	0.	0.
	JUL	3.222E+07	5.471E+04	7.440E+02	0.	0.
	AUG	3.188E+07	5.631E+04	7.440E+02	0.	0.
	SEP	2.676E+07	4.490E+04	7.200E+02	0.	0.
	OCT	2.247E+07	4.442E+04	7.440E+02	0.	0.
	NOV	1.645E+07	4.084E+04	7.200E+02	0.	0.
	DEC	1.423E+07	3.376E+04	7.440E+02	0.	0.
	ANN	2.662E+08	5.631E+04	8.784E+03	0.	0.

Figure 38. Air Handling System Component Load Summary.

AIR HANDLING SYSTEM DESCRIPTION report, produced only if requested under **RUN CONTROL (SYSTEM** report), prints all input values used in the simulation of the specified system, including values specifically input by the user or supplied as defaults by the program. A sample is shown in Figure 39.

Advanced Topics

Other System Parameters

Although many of the parameters in Table 4 are self-explanatory, some descriptive clarification is necessary.

The cold- and hot-deck temperature options, applicable regardless of the system type, are (1) fixed-set point, (2) outside air controlled, and (3) zone controlled. If the fixed-set point option (default) is specified, the specified deck temperature becomes the set point of the deck temperature controller.

If the deck is to be controlled by outside air temperature, linear interpolation is performed between the end points of the specified deck control schedule to determine the deck set point, based on the current outside air temperature. The highest set-point temperature specified in the deck control schedule (65°F [18°C] is the default in the **COLD DECK CONTROL SCHEDULE)** becomes the upper limit for the set point of the deck temperature controller and the lowest temperature (55°F [13°C] is the **COLD DECK CONTROL SCHEDULE** default) becomes the lowest limit. For example, consider the cold deck where

COLD DECK CONTROL = OUTSIDE AIR CONTROLLED;

and the default control schedule

COLD DECK CONTROL SCHEDULE = (55 AT 9Ø, 65 AT 7Ø);

are specified. During the simulation, if the outside temperature at any given hour is 90°F (32°C), the cold deck set point is 55°F (13°C). If the outside air is hotter than 90°F (32°C), the set point remains at 55°F (13°C). If the outside temperature is 80°F (26°C), the deck set-point temperature is 60°F (15°C); if the outside temperature is 70°F (21°C), the cold deck set point is 65°F (18°C). Anytime the outside temperature is below 70°F (21°C), the cold deck set point will remain at 65°F (18°C). Figure 40 illustrates this control strategy.

If the **ZONE CONTROLLED** option is used, the zone requiring the coldest or hottest air determines the set point. Even if the deck temperature is to be zone controlled, the deck control schedule is used to establish the deck set-point temperature. In this case, the temperatures required by zones which need the most heating and cooling take the place of the outside air temperatures. Consequently, the respective cold deck control schedules should have a positive slope rather than the negative slope typical of outside air controlled deck set points. Therefore, if the user specifies a deck to be **ZONE CONTROLLED**, a separate set of defaults is automatically invoked.

If either the hot or cold deck is **ZONE CONTROLLED**, the default control schedule for the specified deck is

HOT DECK CONTROL SCHEDULE = (32 AT 32, 212 AT 212);

and/or

COLD DECK CONTROL SCHEDULE = (32 AT 32, 212 AT 212);

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```
*****************************************************************
*                                                               *
*   A I R   H A N D L I N G   S Y S T E M   D E S C R I P T I O N   *
*                                                               *
*****************************************************************
```

BASIC SYSTEM

SYSTEM NUMBER = 1 SYSTEM LOCATION = 0

SIM. PERIOD = 21JAN1979 - 21JAN1979 NO. OF DAYS IN SIMULATION = 1

TYPE SYS = MULTIZONE NO. DISTINCT ZONES ON SYS. = 10

SYSTEM OPERATION = CONTINUOUS

SEASONAL COMPONENT SCHEDULES

PREHEAT COIL	ON - 1JAN	OFF - 31DEC
HEATING COIL	ON - 1OCT	OFF - 31MAR
COOLING COIL	ON - 1JAN	OFF - 31DEC
HEATREC COIL	ON - 0JAN	OFF - 0JAN

DAILY PREHEAT COIL SCHEDULE T = ON , F = OFF

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
WKEND	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

DAILY HEATING COIL SCHEDULE T = ON , F = OFF

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
WKEND	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

DAILY COOLING COIL SCHEDULE T = ON , F = OFF

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
WKEND	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

DAILY HEATREC COIL SCHEDULE T = ON , F = OFF

HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
WKEND	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

TOTAL SUPPLY FAN PRESSURE = 2.48914 IN-H2O
TOTAL RETURN FAN PRESSURE = 0. IN-H2O
TOTAL EXHAUST FAN PRESSURE = 1.00369 IN-H2O

SUPPLY FAN EFFICIENCY = .70
RETURN FAN EFFICIENCY = .70
EXHAUST FAN EFFICIENCY = .70

MIXED AIR CONTROL = FIXED AMOUNT
FIXED OUTSIDE AIR VOLUME = 4.114E+03 FT**3/MIN
DESIRED MIXED AIR TEMPERATURE = COLD DECK TEMP

Figure 39. Air Handling System Description.

DAILY VENTILATION PROFILES

HOUR	1	2	3	4	5	6	7	8	9	10	11	12
WKDAY MIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WKDAY MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY MIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WKDAY MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	1	2	3	4	5	6	7	8	9	10	11	12
WKEND MIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WKEND MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	13	14	15	16	17	18	19	20	21	22	23	24
WKEND MIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WKEND MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOT DECK CONTROL = OUTSIDE AIR CONTROL
HOT DECK THROTTLING RANGE = 7.20000 DEG. F
HOT DECK CONTROL SCHEDULE = (120.00 AT 10.00 , 80.00 AT 70.00) DEG. F

HEATING COIL CAPACITY = .341E+07 1000BTU/HR
HEATING COIL ENERGY SUPPLY = HOT WATER

COLD DEC CONTROL = FIXED SET POINT
COLD DEC THROTTLING RANGE = 7.20000 DEG. F
COLD DEC FIXED TEMPERATURE = 55.00000 DEG. F

ZONE DATA SUMMARY

ZONE NUMBER	ZONE SUPPLY AIR VOL	ZONE EXHAUST AIR VOL	ZONE REHEAT CAPCTY	ZONE REHEAT ENERGY	ZONE TSTAT BB CAPCTY	ZONE TSTAT BB ENERGY	ZONE MULT
1	1.784E+03	1.000E+03	0.	HOT WATER	0.	HOT WATER	1.0
2	4.060E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
3	2.010E+03	0.	0.	HOT WATER	0.	HOT WATER	1.0
4	7.610E+02	6.000E+02	0.	HOT WATER	0.	HOT WATER	1.0
5	5.020E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
6	8.330E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
7	8.840E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
8	8.290E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
9	2.245E+03	0.	0.	HOT WATER	0.	HOT WATER	1.0
10	2.105E+03	0.	0.	HOT WATER	0.	HOT WATER	1.0

TOTAL DESIGN SUPPLY AIR VOLUME = 1.236E+04

Figure 39. (cont'd)

This is a straight line with a slope of one and arbitrarily high and low limits. It means that the deck set points will be exactly equal to the air temperatures required by the zone which needs the most heating and the zone which needs the most cooling. However, users may wish to limit the upper or lower set-point temperature for the hot or cold deck. For example,

COLD DECK CONTROL SCHEDULE = (55 AT 55, 65 AT 65);

will not allow the cold deck set point to go below 55°F (13°C) or above 65°F (18°C). The user may also add "gain" to the cold deck control strategy:

COLD DECK CONTROL SCHEDULE = (45 AT 55, 65 AT 65);

In this case, if the zone requiring the most cooling is demanding 55°F (13°C) air, the cold deck will be set to 45°F (7°C). If 60°F (15°C) air is required by the critical zone, the cold deck set point will be 55°F (13°C).

Although only the deck *set point* temperature has been referred to, the *actual* deck temperature is also influenced by the deck throttling range. It may also be influenced in the simulation by the ability of the coils to maintain the desired deck temperature.

In *all* cases, regardless of the specified deck control strategy, the deck throttling range is applied as follows: based on the last hour's cooling coil load ratio, the desired cold deck temperature is proportioned to a value between the set point and the set point minus the throttling range. For example, if the last hour's load was 100 percent of the cooling coil capacity, the deck temperature becomes the set point (e.g., 55°F [13°C]). If the last hour's load was 0 percent of the coil capacity, the cold deck temperature becomes the set point minus the throttling range (e.g., 55 - 7.2 or 46.8°F [8.8°C]). If the last hour's cooling coil load was 25 percent of the coil capacity, the cold deck temperature becomes the set point minus 75 percent of the throttling range (55 - 5.4 or 49.6°F [9.8°C]). The exact inverse applies to hot decks; i.e., the deck temperature increases above the set point with decreasing coil load. For deck control schemes where any room thermostat is in direct control of the hot or cold deck, the deck throttling range should be set to zero. For schemes where an air temperature sensor in the hot or cold deck controls the deck temperature (whether or not it is reset by one or more room thermostats), a finite throttling range should be specified since the actual deck temperature must deviate from the deck set point before any control action takes place.

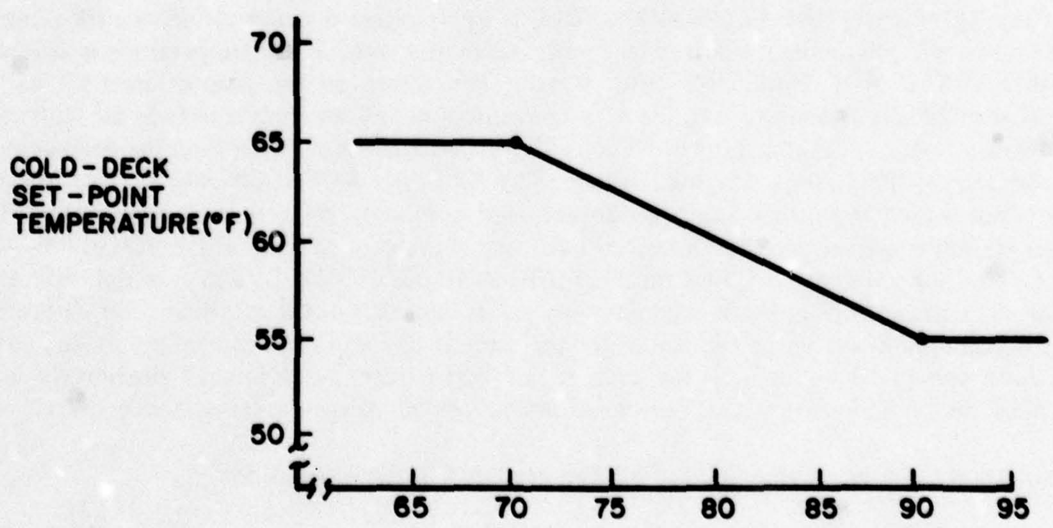

Figure 40. Cold deck set point vs outside air temperature for outside air controlled cold deck and default cold deck control schedule. (Metric conversion factor: °C = [°F - 32] X 5/9)

For VAV, terminal reheat, and subzone reheat systems, the user-specified or default hot deck set point and control scheme are used to determine the maximum allowable temperature of the air leaving the reheat coils. Thus, if the boiler water serving one of these types of systems is adjusted with outdoor air temperature, an appropriate **HOT DECK CONTROL SCHEDULE** should be specified (if the default in inappropriate) and

HOT DECK CONTROL = OUTSIDE AIR CONTROLLED;

should be input under **OTHER SYSTEM PARAMETERS**. If the boiler water temperature is fixed (or if the **REHEAT ENERGY SUPPLY** is not **HOT WATER**), the appropriate fixed **HOT DECK TEMPERATURE** should be specified. BLAST will adjust maximum *air* temperatures (always somewhat lower than *water* temperatures). **HOT DECK THROTTLING** is not used in the simulation of VAV, terminal reheat, and subzone reheat systems.

The mixed-air control includes three economy cycles and two methods for fixing the outside air volume if an economy cycle is not used. If a **FIXED AMOUNT** of air is used, the specified **OUTSIDE AIR VOLUME**, adjusted by the normalized **MINIMUM OUTSIDE AIR SCHEDULES**, is the amount introduced whenever the fan is on. If a **FIXED PERCENT** is specified, the **MINIMUM OUTSIDE AIR SCHEDULES** determine the outside air supplied as a fraction of the total air supply during any hour. These same **MINIMUM OUTSIDE AIR SCHEDULES** also determine the minimum fraction of outside air when economy cycles are used (see following sections). The minimum outside air introduced is never less than the sum of the exhaust air flow specified for the zones on the air handler whenever the fan is running. Thus, a fixed minimum outside air amount for variable volume systems using economy cycles can be specified by selecting **EXHAUST AIR VOLUME** amounts for each zone which sum to the desired fixed amount of outside air.

If the **TEMPERATURE ECONOMY CYCLE** is used, excess outdoor air (above the minimum but less than the maximum) is introduced only when the outside air temperature is below the **DESIRED MIXED AIR TEMPERATURE**. Outside and return air are proportioned to maintain the desired mixed-air temperature (subject to the minimum and maximum outside air constraint). When this economy cycle goes into operation (i.e., the outside air is colder than the desired mixed-air temperature), the cooling coil load is zero. The **RETURN AIR ECONOMY CYCLE** performs similarly, but is used any time the outside air temperature is below the *return air temperature*. Thus, fresh air is used to offset part, but not necessarily all, of the cooling load. The **ENTHALPY ECONOMY CYCLE** operates exactly like the **RETURN AIR ECONOMY CYCLE**, except that excess outdoor air is not introduced unless its enthalpy is less than that of the return air. For all economy cycles, the minimum outside air schedule for the current day and hour multiplied by the current hour's total supply air volume, *or* the sum of the zone exhaust air volumes (whichever is larger) determines the minimum amount of outside air introduced whenever the fan system is on.

Note that the preheat coil, if specified, can be in either of two positions:

1. In the outside air duct
2. In the mixed-air duct.

If the preheat coil is specified as being in the outside air duct, the **PREHEAT TEMPERATURE** is the outside air temperature at which the preheat coil is turned on. Thus, if the preheat coil is in the outside air duct, it is either fully "on" or "off." If the preheat coil is in the mixed-air duct, the pre-

heat coil is assumed to modulate and the **PREHEAT TEMPERATURE** is the temperature to be maintained immediately downstream of the preheat coil. If the preheat coil is in the mixed-air duct, it modulates to maintain the cold deck temperature if **PREHEAT TEMPERATURE** is not specified.

Fan Power Coefficients

Fan power for fixed volume systems and full-load fan power for VAV systems is computed from default or user-specified fan pressure and fan efficiency using basic fan laws. Note that full-load fan efficiency for VAV fans is usually lower than their fixed volume counterparts. Part-load fan power for VAV systems is computed using **VAV VOLUME CONTROL TYPE** *or* **FAN POWER COEFFICIENTS**.

If specified, **FAN POWER COEFFICIENTS** determine the fraction of full-load fan power consumption for variable volume systems according to the following equation:

$$FFLP = A + B \times PLR + C \times PLR^2 + D \times PLR^3 + E \times PLR^4 \qquad [Eq\ 6]$$

where: FFLP = the fraction of full-load power

PLR = the part-load ratio defined as the delivered air flow in any one hour divided by the design air flow rate for the fan

A, B, C, D, and E = are the five fan power coefficients specified within the parentheses in **FAN POWER COEFFICIENTS**. (Any of these coefficients can be zero.)

If the user does not specify **FAN POWER COEFFICIENTS** and is simulating a variable volume fan system, three types of air volume control can be invoked: **DISCHARGE DAMPERS, INLET VANES,** and **VARIABLE SPEED**. Eq 6 is still used but with default coefficients, depending on the type of fan volume control specified. The following **FAN POWER COEFFICIENTS** are used if the user specifies **INLET VANES, DISCHARGE DAMPERS,** or **VARIABLE SPEED FANS**.

For **INLET VANES**:

$$FFLP = .3507123 + .3085 \times PLR - .54137 \times PLR^2 + .871988 \times PLR^3$$

For **DISCHARGE DAMPERS**:

$$FFLP = .3707 + .9725 \times PLR - .3424 \times PLR^2$$

For **VARIABLE SPEED**:

$$FFLP = .00153 + .005208 \times PLR + 1.1086 \times PLR^2 - .11635563 \times PLR^3$$

Figure 41 shows the default curves for FFLP vs PLR for these three types of volume control. Table 7 shows fan power coefficients and recommended minimum fractions for several types of fans and fan control. These data are from a different source than the curves of Figure 41.[4]

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[4]Courtesy of Dr. Swicki Anderson, Department of Mechanical Engineering, Texas A & M University.

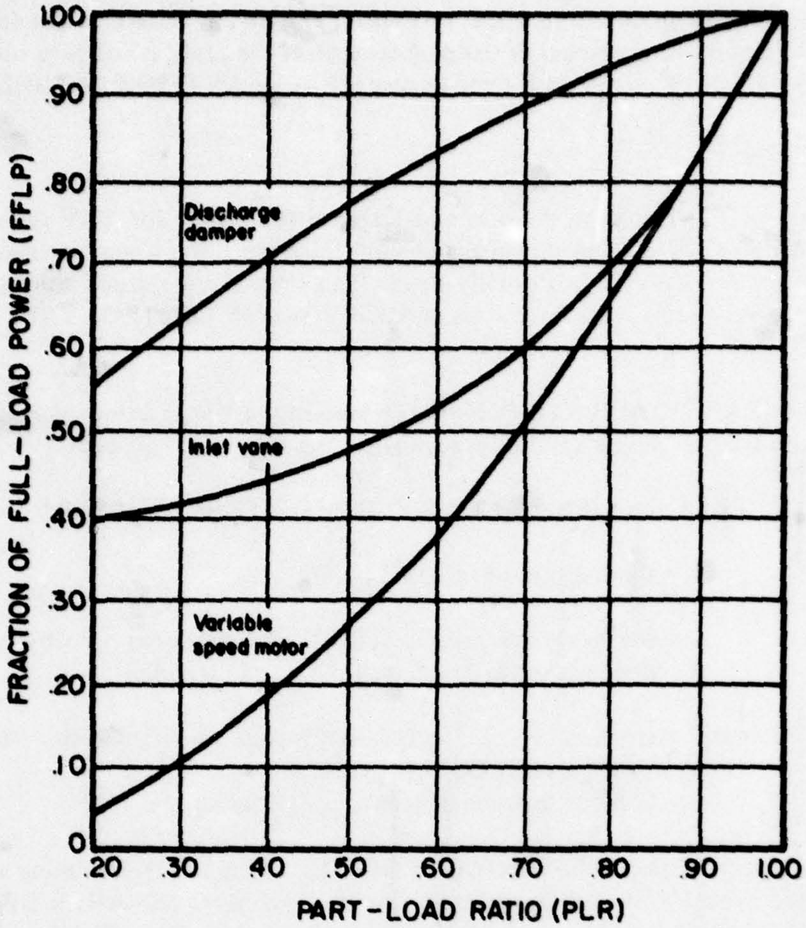

Figure 41. Fractional fan vs air quality reduction for three common methods of controlling duct static pressures (Norm Janisse, "How to Control Air Systems:, HPAC, April 1969, pp. 129–136).

Table 7
Fan Power Coefficients

Type	A	B	C	D	E	Recommended Min Air Frac
2-speedback inclined blade fan	.456119	-4.446907	9.968463	-7.111875	2.110336	.40
Variable pitch vaneaxial fan	41.681062	-142.130930	160.240571	-62.719431	1.849550	.40
Inlet vanes on backward inclined centrifugal fan	1.208550	-5.790262	15.027606	-15.978046	6.551607	.35
Damper control with forward curved centrifugal fan	.489142	-.555283	1.089156	0.0	0.0	.30
Damper control with backward inclined centrifugal fan	-.099583	2.243020	-1.420787	.283400	0.0	.35

6 CENTRAL ENERGY PLANT DESCRIPTION

Central energy plants are most simply described by selecting the generic equipment to be used. With the exception of the number, type, and size of plant components, all other design, equipment performance, and economic parameters have default values which need not be changed to successfully simulate a central energy plant.

The format for describing a central plant is similar to fan system descriptions. That is, the central plant description input data block begins with

BEGIN CENTRAL PLANT DESCRIPTION;

and ends with

END CENTRAL PLANT DESCRIPTION;

(END; is equivalent).

A description of each plant to be simulated begins with a plant identifier statement which specifies its number, name, and the fan systems it serves. END PLANT; terminates the description of each central plant. For example:

Starts the description of all central plants

BEGIN CENTRAL PLANT DESCRIPTION;

Typical required punctuation

Begins description of individual plants

PLANT 4 "BASIC BOILER & CHILLER" SERVING SYSTEM 72;

Equipment selection and other data for this central plant

.
.
.

User specified plant number

Plant title (in quotes)

Number of one or more fan systems served by the plant. ...SERVING ALL SYSTEMS; can also be used if all fan systems simulated are served by a single plant

END PLANT;

Ends first plant (END; is equivalent)

Descriptions of other central plants (may be other options serving the same systems or plants serving other systems or both

.
.
.

END CENTRAL PLANT DESCRIPTION;

Ends description of all central plants (END; is equivalent)

Each plant is described by inputting data in any of 11 data blocks; seven of these deal with plant performance, and four cover economic data. Their syntax is similar to the data block used to describe fan systems.

EQUIPMENT SELECTION:

Type, number, size, and availability of plant components.

END EQUIPMENT SELECTION;

EQUIPMENT ASSIGNMENT:

Defines number and size of each type of equipment which will operate in each specified load range.

END EQUIPMENT ASSIGNMENT;

PART LOAD RATIOS:

Establishes minimum, maximum, and best part load ratios for each type of equipment and the ratio of electrical energy input per unit output.

END PART LOAD RATIOS;

SCHEDULE:

Domestic hot water or other low-grade heat demands not accounted for in simulating fan systems can be added here.

END SCHEDULE;

EQUIPMENT PERFORMANCE PARAMETERS:

Allows coefficients describing the performance of actual equipment to be specified.

END EQUIPMENT PERFORMANCE PARAMETERS;

FOR SYSTEM usn:

Allows system multipliers for duplicate fan systems (i.e., multistory buildings).

END;

LIFE CYCLE COST PARAMETERS:

Defines project life and interest and inflation factors.

END LIFE CYCLE COST PARAMETERS;

ENERGY COST:

Defines unit cost data, rate structures, and energy inflation rates.

END ENERGY COST;

ACTUAL EQUIPMENT COST:

Provides cost data for equipment selected.

END ACTUAL EQUIPMENT COST;

REFERENCE EQUIPMENT COST:

Scales reference costs to allow costing of many different sizes of equipment.

END REFERENCE EQUIPMENT COST;

OTHER COST PARAMETERS:

Allows entry of building and fan system capital and operating costs.

END OTHER COST PARAMETERS;

The central plant identifier and each of these 11 data blocks are described in the following subsections.

Plant Identifier

The syntax for each plant identifier statement is:

PLANT usn1 "ustitle" SERVING SYSTEMS usn2, usn3, . . .;

where:

- usn1 is a user-selected plant number (integer)
- ustitle is the user-specified plant title (in quotes and 40 characters or less).
- usn2, usn3 . . . are the fan systems served by the central plant; these are separated by commas, except for the last system number, where the comma is replaced by a semicolon. Up to 50 systems may be specified.

If all simulated fan systems will be served by the plant, an alternate format can be used:

PLANT usn1 "ustitle" SERVING ALL SYSTEMS;

Equipment Selection

This block specifies the types, numbers and sizes of equipment installed and simultaneously available for a central plant simulation.

For example:

Begins input data block

Equipment type from Table 8

Nominal capacity, 1000 Btu/hr (or KW)

```
EQUIPMENT SELECTION:
3 GAS TURBINE OF SIZE 1ØØØ
    (2 AVAILABLE);
1 GAS TURBINE OF SIZE 5ØØØ;
1 CHILLER OF SIZE 2ØØØ;
1 BOILER OF SIZE 2ØØØ;
  .
  .
  .
```

Integer number of pieces of equipment of a given type

Number available which can be operated simultaneously. Can be omitted; if so, all units are available.

Among CHILLER, OPEN CHILLER, and RECIPROCATING CHILLER, only one type may be specified.

Other equipment, if any

END EQUIPMENT SELECTION;

Ends input data block.
END; is equivalent

The general syntax for EQUIPMENT SELECTION is

Typical required punctuation

EQUIPMENT SELECTION:

usn1 type1 OF SIZE usn2 (usn3 AVAILABLE);

•

•

•

END EQUIPMENT SELECTION:

where: usn1 is the number of pieces of equipment of type1 and of size usn2.
usn3 is the number available and must be less than or equal to usn1 (allows for standby units).

Up to six different sizes of each equipment type may be specified. If different sizes will be used, they should typically be entered in ascending order, since default operating rules discussed later will cause at least one of the last sizes specified to operate when there is a demand (see *Default Operating Rules* and *Sequencing Rules* of Appendex G). While only two gas turbines of size 1000 may operate simultaneously in the previous example, costs will be computed for all three. If the number available is *not* specified, it is assumed to be the number installed. For solar collectors, size is the *area* of each collector in sq ft (m^2). For example,

1ØØ SOLAR COLLECTORS OF SIZE 21;

means 100 collectors of 21 sq ft (2 m^2) each for a total array area of 2100 sq ft (200 m^2).

Capacities for hot and cold storage tanks are in kBtu (kWh). A minimal central plant description would be, for example,

BEGIN CENTRAL PLANT DESCRIPTION;

PLANT 1 "MOTEL" SERVING ALL SYSTEMS;

EQUIPMENT SELECTION:

1 BOILER OF SIZE 5ØØ;

END EQUIPMENT SELECTION;

END; is equivalent

END PLANT;

END CENTRAL PLANT DESCRIPTION;

with all other parameters as well as life-cycle costing, taking on default values.

The following are allowable names for equipment types:

Table 8
Allowable Equipment Types

Equipment Type Name	Units for Size Specification English	SI
BOILER	1000 Btu/hour	kW
CERAMIC COOLING TOWER	1000 Btu/hour	kW
CHILLER	1000 Btu/hour	kW
COLD STORAGE TANK	1000 Btu	kWh
COOLING TOWER	1000 Btu/hour	kW
DIESEL GENERATOR	1000 Btu/hour	kW
DOUBLE BUNDLE CHILLER	1000 Btu/hour	kW
GAS TURBINE	1000 Btu/hour	kW
HEAT PUMP	1000 Btu/hour	kWh
HOT STORAGE TANK	1000 Btu	kW
ONE-STAGE ABSORBER	1000 Btu/hour	kW
OPEN CHILLER	1000 Btu/hour	kW
RECIPROCATING CHILLER	1000 Btu/hour	kW
SOLAR COLLECTORS	sq ft	m^2
STEAM TURBINE	1000 Btu/hour	kW
TWO-STAGE ABSORBER	1000 Btu/hour	kW
TWO-STAGE ABSORBER W/ECON	1000 Btu/hour	kW

CHILLER is a hermetic centrifugal chiller; OPEN CHILLER is a non-hermetic (open) centrifugal chiller.

Hot water, chilled water, and condenser water pumps are automatically modeled. (See Appendix G for discussion). When exercising two equipment selection options during the same run for the purpose of comparison or optimization, the form might be:

```
BEGIN CENTRAL PLANT DESCRIPTION;
    PLANT 7 "CAFE" SERVING ALL SYSTEMS;
        EQUIPMENT SELECTION:
            1 BOILER OF SIZE 500;
            1 CHILLER OF SIZE 500;
        END EQUIPMENT SELECTION;
    END PLANT;
    PLANT 10 "CAFE" SERVING ALL SYSTEMS;
        EQUIPMENT SELECTION:
```

```
1 BOILER OF SIZE 5ØØ;

2 CHILLERS OF SIZE 25Ø (2 AVAILABLE);

END EQUIPMENT SELECTION;

END PLANT;

END CENTRAL PLANT DESCRIPTION;
```

Under certain circumstances, a user may wish to calculate life-cycle cost for a building and fan system which has no central plant (i.e., a DX condensing unit system with electric heat). In this case, the EQUIPMENT SELECTION data block may be omitted (a "dummy" central plant identifier is still required, including the identification of the zones being served; applicable building, fan system, and energy cost data can be entered, as required).

Equipment Assignment

The default equipment allocation strategy described in Appendix G can be overridden in whole or in part by using equipment assignment tables. For example:

```
EQUIPMENT ASSIGNMENT:
GAS TURBINE:
FOR L = .5 USE (1,Ø),
FOR L = 1.8 USE (2,Ø),
FOR L = 3.Ø USE (Ø,1),
FOR L = 7.Ø USE (2,1);
.
.
.
END EQUIPMENT ASSIGNMENT
```

- **Begins input data block** (EQUIPMENT ASSIGNMENT:)
- **Equipment type for which assignment tables apply** (GAS TURBINE:)
- **Upper load limit in kBtu/hr (or kW)**
- **Load ranges in this example are 0 to 0.5 kBtu/hr, .5 to 1.8, 1.8 to 3.0, 3.0 to 7.0, and 7.0 above.**
- **Number of gas turbines of first-specified size which will operate to meet loads between 0 and 0.5.**
- **Number of gas turbines of second-specified size allowed to operate on loads between 0.5 and 1.8.**
- ***Required* after specification of last load range.**
- **Last load range should include all available units of all sizes.**
- **Maximum load range.**
- **Next equipment types, if any. If assignment is not made, the default assignment scheme of Appendix G applies to omitted equipment.**
- **Ends input data block, END; is equivalent**

Each equipment type selected in EQUIPMENT SELECTION may be entered once.

For each load range, equipment units allowed to operate share the load in proportion to their capacities.

Since up to six different sizes of each equipment type can be selected, the general form of the assignment table entry is:

FOR L = usn USE (I, J, K, L, M, N),

Up to 10 load ranges are allowed. The number of integers within the parentheses should correspond to the number of different sizes selected in the equipment selection sequence.

Part-Load Ratios

Whether each equipment type operates and at what level it operates depend on its part-load ratio parameters. The format for using this part-load ratio block to override the default values is:

Minimum part-load ratio below which the electricity or fuel consumption is constant

Begins input data block

Most efficient (or best) part-load ratio

```
PART LOAD RATIOS;

GAS TURBINE (MIN=.Ø2,MAX=1.2,BEST=.7,ELECTRICAL=Ø,Ø);

BOILER (MIN=.Ø2,MAX=1.Ø,BEST=.85,ELECTRICAL=Ø.Ø);
 .
 .
 .
CHILLER (MIN=.1,MAX=1.Ø5,BEST=.65,ELECTRICAL=.2275);
 .
 .
 .
 .
END PART LOAD RATIOS;
```

Dimensionless ratio of full-load electrical input to nominal capacity

Equipment type from Table 9

Maximum part-load ratio allowed

Next equipment type, if any. If omitted, values from part-load ratio default table are used.

Ends input data block. END; is equivalent.

Each equipment type, *except* solar collectors, hot storage tank, and cold storage tank, which are excluded, may be entered once, so values apply to all sizes of each type.

Some or all of the values for an equipment type may be entered. If omitted, they default to the basic part-load ratio data in Table 9.

Boilers may have feed water pumps and draft fans which would make the electrical input-to-nominal capacity ratio slightly larger than zero. For electrically driven chillers, this ratio is large, since it represents the energy required per unit of cooling capacity. The default of .2275 corresponds to approximately .8 kW/ton. To convert kilowatt/ton to the appropriate dimensionless ratio, multiply by 0.2843.

For cooling towers, BEST and ELECTRICAL have the following meanings:

ELECTRICAL = ratio of fan power to cooling tower capacity
BEST = best part-load ratio when using more than one cooling tower

Table 9
Default Part-Load Ratios

Equipment Type	Part-Load Ratios			Electric Input to Nominal Capacity Ratio (Dimensionless)
	Minimum	Maximum	Optimum	
BOILER	.0100	1.0000	.8700	0.0000
CERAMIC COOLING TOWER	0.0000	N/A	.4365	.0120
CHILLER	.1000	1.0500	.6500	.2275
COLD STORAGE TANK	N/A	N/A	N/A	N/A
COOLING TOWER	0.0000	N/A	.4365	.0120
DIESEL GENERATOR	.0200	1.0500	.6000	0.0000
DOUBLE BUNDLE CHILLER	.1000	1.0500	.6500	.2275
GAS TURBINE	.0200	1.0500	.6000	0.0000
HEAT PUMP	.1000	1.0500	.6500	.2275
HOT STORAGE TANK	N/A	N/A	N/A	N/A
ONE STAGE ABSORBER	.0500	1.1000	.6500	.0077
OPEN CHILLER	.1000	1.0500	.6500	.2275
RECIPROCATING CHILLER	.1000	1.0500	.6500	.2275
SOLAR COLLECTORS	N/A	N/A	N/A	0.0
STEAM TURBINE	.0200	1.1000	.9000	0.0000
TWO STAGE ABSORBER	.0500	1.1000	.6500	.0077
TWO STAGE ABSORBER W/ECON	.0500	1.1000	.6500	.0077

Schedule

If there is demand for domestic hot water or other heat energy, the SCHEDULE input data block should be entered. If there is no demand, it is omitted. The following is an example:

Begins input data table

Heat energy demanded in kBtu/hour (or kW)

```
SCHEDULE:
   WEEKDAY HOT WATER=(Ø2 TO Ø6–Ø,Ø6 TO 19-5Ø,19 TO Ø2-1Ø);
   WEEKEND HOT WATER=)ØØ TO 24–Ø);
END SCHEDULE;
```

Time span for demand. Here, from 7 pm to midnight, and from midnight to 2 am on any weekday

Ends input data block. END; is equivalent

Both weekday and weekend must be specified. An entry for holidays is *not* needed.

These domestic hot water schedules do *not* go into the library and should not be confused with the general schedules and control schedules discussed in Chapter 3.

Special Parameters

SPECIAL PARAMETERS are additional constants needed to simulate central energy plants. These constants include boiler and chiller operating temperatures, heat content of fuels, system pressures and flow rates, and the efficiency of off-site power stations and others. The format of this block is:

```
                         Begins input data block
SPECIAL PARAMETERS:

                TOTUEF = .27:
Parameter names
                RFLASH = .10;
                                              New values for parameters
                .
                .
                .                             Remaining special parameters, if any.
                .

END SPECIAL PARAMETERS;
        Ends input data block. END; is equivalent.
```

Table 10 shows which special parameters are normally associated with a particular equipment type. Complete entry of special parameters for gas turbines would be:

```
SPECIAL PARAMETERS:

    .
    .
    .                              Special parameters associated with gas turbines.
    TSATUR =          ;
    RMXKWG =          ;
    TOTUEF =          ;            Special parameters for other equipment types.
    .
    .
    .
    .
END SPECIAL PARAMETERS;
```

Entries for parameters may be in any order.

Some or all of the special parameters may be entered. Omitted ones will take the default values give in Table 11.

Table 10
Equipment Type

Special parameters employed for each equipment type

Special Parameter Name	Special Parameter Description	GAS TURBINE	DIESEL GENERATOR	BOILER	ONE-STAGE ABSORBER	TWO-STAGE ABSORBER	TWO-STAGE ABSORBER W/ECON	CHILLER	OPEN CHILLER	RECIPROCATING CHILLER	DOUBLE BUNDLE CHILLER	COOLING TOWER	CERAMIC COOLING TOWER	SOLAR COLLECTORS	STEAM TURBINE	HOT STORAGE TANK	COLD STORAGE TANK	HEAT PUMP	PUMPS
AZMUTH	Collector Array Azimuth Angle													●					
FLOWRT	Mass Flow/Collector Area													●					
HFUELB	Heat Content of Fuel			●															
HTXEFF	Tank-Collector Ht Excgr Effectiveness													●					
MXTNKT	Maximum Solar Tank Temp													●					
PELCL	Elect Inp. to Circ. Pump/Cooling Load																		●
PELHT	Elect Inp. to Circ. Pump/Heating Load																		●
PELTWR	Elect Inp. to Tower/Tower Cool Load				●	●	●	●	●	●	●	●	●						●
PSTEAM	Steam Pressure	●	●	●	●	●	●												
PSTMTUR	Entering Steam Press														●				
RAVRHDB	Availbl Recvrbl Ht Ratio										●								
RAVRHHP	Availbl Recvrbl Ht Ratio																	●	
RFLASH	Boiler Flash Water/Steam Feed			●															
RHFLASH	Recovd Heat/Flash Steam Energy			●															
RMXKWD	Max Exh Flow/KW Output		●																
RMXKWG	Max Exh Flow/KW Output	●																	
RPMNOM	Nom Speed, RPM														●				
RWCA	Tower Water/Absor Chilr Capac				●	●	●					●	●						
RWCC	Tower Water/Compr Chilr Capac							●	●	●		●	●						
RWCDB	Tower Water/Dbund Chilr Capac										●	●	●						
RWCHP	Tower Water/Ht Pump Capac											●	●					●	
RWSTUR	Condensate/Entering Steam														●				
SRATB	Air, Fuel Stoich Ratio			●															
STEAM	Steam Enthalpy	●	●	●	●	●	●												
TNKTEM	Initial Tank Temperature													●					
TCOOL	Chilled Water Temp							●	●	●	●							●	
TCW	Leaving Condenser Water Temp										●								
TILT	Solar Collector Tilt Angle													●					
TLEAVE	Boiler Stack Leaving Temp			●															
TMINC	Min Tank Temp for Cooling				●									●					
TMINH	Min Tank Temp for Heating													●					
TMINHP	Min Tank Temp for Ht Pump													●				●	
TNKCAP	Storage Tank Cap/Col. Area													●					
TOTUEF	Tot Effic of Util Elec Generation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
TOWOPR	Tower Operation Type											●	●						
TSATUR	Steam Saturation Temp	●	●	●	●	●	●												
TSTMTUR	Entering Steam Temp														●				
TTOWR	Minimum Leaving Tower Water Temp				●	●	●	●	●	●	●	●	●					●	
TWMAKE	Make Up Water Temp			●															

Table 11
Special Parameters Table

Special Parameter Name	Special Parameter Description	Default Value (English)
AZMUTH	Collector Array Azimuth Angle	180.0000
FLOWRT	Mass Flow/Collector Area	9.2167
HFUELB	Heat Content of Fuel	20013.3845
HTXEFF	Tank-Collector Ht Excgr Effectiveness	.9000
MXTNKT	Maximum Solar Tank Temp	212.0000
PELCL	Elect Inp. to Circ. Pump/Cooling Load	.0180
PELHT	Elect Inp. to Circ. Pump/Heating Load	.0060
PELTWR	Elec Inp. to Tower/Tower Cool Load	.0130
PSTEAM	Steam Pressure	284.4099
PSTMTUR	Entering Steam Press	6920.1708
RAVRHDB	Availbl Recvrbl Ht Ratio	.9500
RAVRHHP	Availbl Recvrbl Ht Ratio	.9500
RFLASH	Boiler Flash Water/Steam Feed	.0710
RHFLASH	Recovd Heat/Flash Steam Energy	.5000
RMXKWD	Max Exh Flow/KW Output	1.4644
RMXKWG	Max Exh Flow/KW Output	11.7152
RPMNOM	Nom Speed, RPM	3600.0000
RWCA	Tower Water/Absor Chilr Capac	124.8226
RWCC	Tower Water/Compr Chilr Capac	124.8226
RWCDB	Tower Water/Dbund Chilr Capac	124.8226
RWCHP	Tower Water/Heat Pump Capac	124.2230
RWSTUR	Condensate/Entering Steam	.9700
SRATB	Air, Fuel Stoich Ratio	17.0000
STEAM	Steam Enthalpy	1168.6785
TNKTEM	Initial Tank Temperature	140.0000
TCOOL	Chilled Water Temp	44.0060
TCW	Leaving Condenser Water Temp	110.0000
TILT	Solar Collector Tilt Angle	40.0000
TLEAVE	Boiler Stack Leaving Temp	550.0400
TMINC	Min Tank Temp for Cooling	179.9960
TMINH	Min Tank Temp for Heating	100.0040
TMINHP	Min Tank Temp for Ht Pump	79.8800
TNKCAP	Storage Tank Cap/Col. Area	10.240[illegible]
TOTUEF	Tot Effic of Util Elec Generation	.3000
TOWOPR	Tower Operation Type	2.0000
TSATUR	Steam Saturation Temp	241.5302
TSTMTUR	Entering Steam Temp	572.0000
TTOWR	Minimum Leaving Tower Water Temp	60.0080
TWMAKE	Make Up Water Temp	55.0040

The meaning and effect of each special parameter is described below. It should be studied carefully since defaults may be appropriate only for very conventional plants.

AZMUTH Compass azimuth angle direction that the solar collectors are facing.
Units: degrees.

FLOWRT Mass flow of water through solar collectors (equivalent mass flow if other fluids are used) per unit collector area. If fluids other than water are used, the actual

flow rate should be multiplied by the specific heat ratio of the other fluid to water in order to compute **FLOWRT**.

Unit: lb/hour-sq ft (kg/sec-m^2).

HFUELB Heat content of fuel. Affects boiler efficiency and should be consistent with **SRATB**.

Units: Btu/lb (kJ/kg).

HTXEFF Effectiveness of heat exchanger between solar collector fluid loop and thermal storage tank fluid loop. If non exists, use 1.0.

Units: dimensionless.

MXTNKT Maximum allowable solar storage tank temperature.

Units: °F (°C).

PELCL Ratio of electrical energy for circulatory pumps to cooling load. Refer to **EQUIPMENT PERFORMANCE PARAMETERS – PUMPS** in Appendix G.

Units: dimensionless.

PELHT Ratio of electric energy for circulatory pumps to heating load. Refer to **EQUIPMENT PERFORMANCE PARAMETERS – PUMPS** in Appendix G.

Units: dimensionless

PELTWR If cooling towers are specified in the input, **PELTWR** is the ratio of pump electical energy required to cooling tower load. Refer to **EQUIPMENT PERFORMANCE PARAMETERS – COOLING TOWERS** in Appendix G. If cooling towers are not specified in the input, **PELTWR** is the ratio of tower pump electrical energy required to cooling tower load. If no tower is specified, the total electrical demand for towers and pumps is (**PELTWR** + **ELECTRICAL**) X (Tower Load) where **ELECTRICAL** is the power consumption per unit load for towers from **PART LOAD RATIOS**.

PSTEAM Gauge boiler steam pressure, unless steam turbines are selected (equivalent saturation pressure for hot water boilers). If not specified, default is 285 in. water gauge (10.3 psig [71016 Pa]); if two-stage absorber is selected, default is 3990 in. water gauge (144 psig [992845 Pa]). Also, steam turbine exhaust pressure if steam turbines are specified.

Units: in. water gauge (pascals gauge), 1 psi = 27.71 in. water gauge.

PSTMTUR Entering steam pressure to steam turbines.

Units: in. water gauge (pascals gauge), 1 psi = 27.71 in. water gauge.

RAVRHDB Fraction of the available double-bundle chiller condenser heat which is recoverable. The calculated condenser heat available at the part- or full-load condition under which the double-bundle chiller is operating in any hour is multiplied by this number to determine the total heat from the double bundle which can meet heating loads.

Units: dimensionless.

RAVRHHP	Same as RAVRHDB, but applies to heat pumps.
REFLASH	The boiler flash water or blowdown rate (pounds of steam discharged per pound of steam produced). For water boilers, this parameter should probably be set to zero (no water loss). Units: dimensionless.
RHFLASH	Fraction of heat in boiler flash (blowdown) which is recovered in feedwater preheater. Units: dimensionless.
RMXKWD	Maximum exhaust flow per unit capacity for diesel engines. The parameter sets an upper limit on exhaust gas flow and exhaust gas heat recovery for diesel engines. Units: lb/hour per kBtu/hour of capacity (kg/sec per kW capacity).
RMXKWG	Same as RMXKWD, but applies to gas turbines.
RPNOM	Steam turbine rotative speed. Units: revolutions per minute (RPM).
RWCA, RWCC RWCDB, and RWCHP	Ratio of tower (condenser) water flow rate to chiller capacity. Used for absorber, compression chillers, double-bundle chillers, and heat pumps, respectively. Units: lb/hour per kBtu/hour of capacity (kg/sec per kW capacity). Note: 1 GPM/ton = 41.7 lb/hour per kBtu/hour. The default is approximately 3 GPM/ton.
RWSTUR	Ratio of condensate flow to entering steam flow for steam turbines. Accounts for steam and/or condensate leaks in the turbine. Units: dimensionless.
SRATB	Air-to-fuel stoichiometric ratio (pounds of air per pound of fuel) for boilers. Affects boiler efficiency and should be consistent with HFUELB. Units: dimensionless.
STEAM	Enthalpy of steam from boiler or heat recovery; also enthalpy of steam to absorbers. If not specified, STEAM will be calculated as the saturation enthalpy at PSTEAM and TSATUR. Units: Btu/lb (kJ/kg).
TNKTEM	Initial solar storage tank temperature. Units: °F (°C).
TCOOL	Temperature of chilled water leaving the chiller. Units: °F (°C).
TCW	Temperature of the water leaving the condenser for double-bundle chillers and heat pumps when they are supplying heat. Units: °F (°C).

TILT	Tilt angle from horizontal of solar collectors. Units: degrees.
TLEAVE	Temperature of flue gas leaving the boiler stack. Affects boiler efficiency and should be the same as the stack temperature used to compute the **RFUELB** equipment performance parameter set (see Appendix G). Units: °F (°C).
TMINC	Minimum storage tank temperature below which cooling cannot be accomplished with solar energy. Units: °F (°C).
TMINH	Minimum storage tank temperature below which heating cannot be accomplished with solar energy. Units: °F (°C).
TMINHP	Minimum solar storage tank temperature below which false loading of the heat pump cannot be accomplished with solar energy. Units: °F (°C).
TNKCAP	Solar thermal storage capacity per unit collector area. Units: lb/sq ft (kg/m^2)
TOTUEF	Total efficiency of the utility producing the purchase power used. Units: dimensionless.
TOWOPR	Tower operation type: 1 or 2 1 = variable water flow rate 2 = fixed water flow rate.
TSATUR	Steam saturation temperature or boiler hot water temperature; also inlet temperature to absorber at full capacity; also temperature at which heat will be recovered from diesel and gas turbine engine generators. If not specified, **TSATUR** will be calculated on the basis of **PSTEAM**. Units: °F (°C).
TSTMTUR	Entering steam temperature to steam turbines. Units: °F (°C).
TTOWR	Minimum allowable temperature for water leaving the cooling tower. Also, initial temperature of water leaving the cooling tower. Units: °F (°C).

Equipment Performance Parameters

While there are generic models for each central plant component in the BLAST program, users may supply specific component performance coefficients to override these defaults and model one or more products of a particular manufacturer. The syntax for changing the defaults via this block is:

Begin input data block

```
EQUIPMENT PERFORMANCE PARAMETERS:
   RFUELB (.8Ø1,.4Ø5,-.235);
      .
      .
      .
      .
END EQUIPMENT PERFORMANCE PARAMETERS;
```

Name of equipment performance parameter.

Ordered set of three coefficients of a quadratic least squares fit to tabular data. The form is $f(x)=a_0+a_1x+a_2x^2$. So, here, $f(x)=.801+.405x-.235x^2$. See Appendix G for details.

Performance parameters of other equipment types. All parameters have *identical* entry format.

Ends input data block. END; is equivalent

Parameters may be entered in any order; some or all may be entered.

Parameters apply to all units of a given equipment type, so each parameter may appear only once.

Omitted parameter-type combinations default to the generic values shown in Appendix G.

Least square fits can easily be done by electronic calculator or digital computer.

Detailed procedures for arriving at coefficient values for parameters associated with each equipment type are contained in Appendix G. Each procedure shows the calculation method appropriate to one or a group of equipment types.

For System Parameters

This parameter block provides for accounting for duplicate fan system loads in the plant simulation. The block format is as below:

Begins input data block

```
FOR SYSTEM 15;
    SYSTEM MULTIPLIER = 3;
END;
```

System number of one of those served by the central plant.

The loads from fan system 15 are multiplied by 3.

Ends input data block

This block may appear for some or all fan systems in the central plant being simulated.

If this block is omitted for a particular fan system, that system will be represented once.

The utility of this block is seen by considering a case in which many fan systems are identical, e.g., middle stories of a skyscraper. An equivalent, but cumbersome way to do this otherwise would be:

```
CENTRAL PLANT 1 "MIDDLE SKYSCRAPER" SERVING
SYSTEMS 1Ø, 15, 15, 15, 4;
```

Life-Cycle Cost Parameters

This parameter set is one of four which allow users to override default costs used to determine the present worth of a simulated building, fan system, and central plant. (See Appendix H for life-cycle cost equations used.) The complete example below shows the defaults for this group of parameters.

```
LIFE CYCLE COST PARAMETERS;          <- Begins input parameter block
    INTEREST RATE = 1Ø;              |
    LABOR INFLATION = Ø;             |- Annual percent
    SUPPLIES INFLATION = Ø;          |
    PROJECT LIFE = 25;               <- Years
    UNIT LABOR COST = 2Ø;            <- Dollars per hour
    ADJUSTMENT FACTOR = 1.Ø;         <- Multiplies all annual and future periodic
                                        dollar costs associated with life cycle
                                        costing. Not applied to first costs.
    PAYMENT TIME = Ø.5;              <- Point of accounting year at which payment
                                        is made, e.g., 0.5 is midyear and 1.0 is
                                        end of year.
END LIFE CYCLE COST PARAMETERS;      <- Ends input parameter block.
                                        END; is equivalent.
```

Some or all of the parameters may be entered.

INTEREST RATE is the interest or discount rate to be used in the lifecycle cost analysis (the time value of money). LABOR INFLATION and SUPPLIES INFLATION are usually viewed as the differential inflation (over and above general inflation). They are used to calculate maintenance and replacement costs, but *do not* apply to energy costs. UNIT LABOR COST is used to compute central plant maintenance cost. ADJUSTMENT FACTOR is typically used to adjust annual and recurring costs (which do not begin until construction of a project is complete) back to the midpoint of construction (the point in time corresponding to capital cost estimates).

Energy Cost

Utility or energy costs are specified using the energy cost block, thus overriding the default energy cost values. There are four energy types:

ELECTRICITY
DIESEL FUEL
GAS TURBINE FUEL
BOILER FUEL

The cost of supplied energy, in dollars per unit of energy, may be charged at either a uniform rate or a stepwise nonuniform rate. Therefore, there are two distinct formats for this block, as illustrated below.

First, for a uniform energy charge rate:

```
ENERGY COST:
    ELECTRICITY:
        ENERGY UNIT = 3.412,
        UNIT COST = Ø.Ø3,
        COST ESCALATION FACTOR = Ø,
        MINIMUM MONTHLY CHARGE = Ø.
        MINIMUM PEAK LOAD = 4Ø,
        DEMAND CHARGE = 1.Ø5,
        INFLATION = 7.5;
        .
        .
        .
        .
END ENERGY COST;
```

Begins input data block

Purchased energy type.

Energy units as charged (kBtu[kWh]) (see following paragraph).

Uniform dollar cost per energy unit. (See following paragraph).

Multiplies the first-year energy cost to give the present worth of energy over the project life, i.e., the present worth factor. If not entered or set to zero, the interest rate value from LIFE CYCLE COST PARAMETERS and the inflation value specified here are used to calculate it for each given energy type.

Minimum monthly dollar charge, independent of usage.

Actual monthly peak load in kBtu (kWh) is calculated. The larger of the actual and minimum is multiplied by demand charge to give demand surcharge.

Demand charge is in dollars per energy unit.

Semicolon ends parameters of this energy type.

Energy type inflation (usually in addition to general inflation rate), in percent.

Next energy types and parameters, if any.

End input data block. END; is equivalent

Some or all of the four energy types may be entered in any order, and some or all of the parameters of each type may be in any order. Table 12 shows default **ENERGY COST** data.

The **ENERGY UNIT** specified in kBtu (kWh) is the energy unit to which demand charges and block or unit cost charges are applied. In the example for specification of purchased electricity cost, 3.412 kBtu = 1 kWh. There are typically about 150 kBtu (44 kWh) per gallon of fuel oil and 1000 kBtu (293 kWh) per 1000 cu ft (8.3 m^3) of natural gas.

For nonuniform stepwise energy charge rates, the **BLOCKS** statement must be entered. Whenever it is entered as a parameter, the **UNIT COST** statement acts as a two-way switch, depending on whether the value is positive or negative.

The two cases are illustrated below:

```
ENERGY COST:

    ELECTRICITY:
       .
       .
       .
       UNIT COST =-1,
       .
       .
       .
       BLOCKS = (5Ø,.Ø2)(75,.Ø15);
       .
       .
       .
END ENERGY COST;
```

Negative value for unit cost calculates charges as follows:

First 50 energy units used cost 2 cents per unit.

Second 75 energy units cost 1.5 cents per unit. Use beyond 125 units is at 1.5 cents, the last price entered.

Next energy types and parameters, if any.

```
ENERGY COST:
    ELECTRICITY:
       .
       .
       .
       UNIT COST = 1,
       .
       .
       BLOCKS = (5Ø,.Ø2)(75,.Ø15);
       .
       .
       .
END ENERGY COST;
       .
       .
       .
```

Positive value for unit cost calculates changes as follows:

First (50 × monthly peak load) units cost 2 cents per unit.

Second (75 × monthly peak load) units cost 1.5 cents per unit. Use beyond this is at 1.5 cents, the last price entered.

Next energy types and parameters, if any

Ten pairs of values may be entered in **BLOCK**.

Table 12
Default Values for Energy Cost Block

	ELECTRICITY	DIESEL FUEL	GAS TURBINE FUEL	BOILER FUEL
ENERGY UNIT	3.414	130.090	1000.427	1000.427
UNIT COST	.04	.40	1.50	1.50
COST ESCALATION FACTOR	0.0	0.0	0.0	0.0
MINIMUM MONTHLY CHARGE	0.0	0.0	0.0	0.0
MINIMUM PEAK LOAD	50.0	0.0	0.0	0.0
DEMAND CHARGE	1.00	0.0	0.0	0.0
INFLATION	7.0	8.0	8.0	8.0

Reference Equipment Cost

This parameter block provides for modification of the basic Table 13, which gives the default cost values for types of central plant equipment.

Its format is illustrated below.

```
REFERENCE EQUIPMENT COST:
    GAS TURBINE:
        SIZE = 2500,
        INSTALLATION COST FACTOR = 1.2,
        COST = 600000,
        MAJOR OVERHAUL COST = 15000,
        MINOR OVERHAUL COST = 1000,
        CONSUMABLES = 1.0,
        MAINTENANCE = 300,
        HOURS TO MAJOR OVERHAUL = 15000,
        HOURS TO MINOR OVERHAUL = 1000,
        LIFE = 100000;
    .
    .
    .
    .
    .
END REFERENCE EQUIPMENT COST;
```

- REFERENCE EQUIPMENT COST: — Begins input data block
- GAS TURBINE: — Equipment type
- SIZE — Equipment size in kBtu/hour (kW)
- INSTALLATION COST FACTOR — Ratio of installed cost-to-equipment cost
- COST — Capital dollar cost for the given size
- MAJOR OVERHAUL COST, MINOR OVERHAUL COST — Dollar cost per overhaul
- CONSUMABLES — Dollar cost per operating hour. Excludes primary fuel.
- MAINTENANCE — Routine maintenance hours per year. Multiplying these hours by the unit labor cost from LIFE-CYCLE COST PARAMETERS gives annual maintenance cost.
- HOURS TO MAJOR OVERHAUL, HOURS TO MINOR OVERHAUL — Operating hours between overhauls.
- LIFE — Hours of equipment lifetime. Equipment is replaced after it operates for this specified number of hours.
- ; — Required terminator for this type
- . . . — Other equipment types, if any.

Some or all equipment types may be entered.

Some or all parameters of an equipment type may be entered.

If block is omitted, values default to those shown in Table 13.

See Equipment Cost Default Logic for results of partial missions.

Actual Equipment Cost

If known or estimatable actual cost parameters for equipment may be input for any equipment *type-size* combination, they will override the reference costs for a given type-size.

The format for this block is shown below:

Begins input data block

```
ACTUAL EQUIPMENT COST:
     GAS TURBINE:
          SIZE = 25ØØ,
          INSTALLATION COST FACTOR = 1.2,
          COST = 8ØØØØØ,
          MAJOR OVERHAUL COST = 12ØØØ,
          MINOR OVERHAUL COST = Ø,
          CONSUMABLES = 1.2,
          MAINTENANCE = 36Ø,
          HOURS TO MAJOR OVERHAUL = 3ØØØØ,
          HOURS TO MINOR OVERHAUL = 12ØØ,
          LIFE = 15ØØØØ;
  .
  .
  .
END ACTUAL EQUIPMENT COST;
```

This parameter block is formatted exactly like the REFERENCE EQUIPMENT COST block.

Equipment type *and* size *must* match one specified in the EQUIPMENT SELECTION block. If actual equipment cost data are omitted for any type and size, REFERENCE EQUIPMENT COST values will be used.

Required terminator for this type

See REFERENCE EQUIPMENT COST for explanation of these parameters.

Next equipment type, if any. May be the same type of different size or a different type.

Some or all equipment type-size combinations may be entered.

Except for SIZE, some or all parameters of an equipment type may be entered. SIZE is required.

If the ACTUAL EQUIPMENT COST block is omitted, values default to modified or basic REFERENCE EQUIPMENT COSTS.

See Equipment Cost Logic for results of partial omissions.

Table 13
Reference Equipment Cost Table

Reference Equipment Cost Default Values

Equipment Type	Size (KBTUH)	Size (kW)	Unit Cost (k$)	Installed Cost Factor	Consumables ($/hr)	Maintenance (hr/yr)	Equipment Life (hrs)	Hours to Minor Overhaul	Minor Overhaul Cost ($)	Hours to Major Overhaul	Major Overhaul Cost ($)
BOILER	40000.4	11723.0	300.000	1.400	0.000	900.0	200000.	10000.	2000.	50000.	25000.
CERAMIC COOLING TOWER	12000.5	3517.0	90.000	1.200	0.000	40.0	20000.	10000.	5000.	50000.	15000.
CHILLER	12000.5	3517.0	100.000	1.200	0.000	500.0	100000.	20000.	5000.	50000.	15000.
COLD STORAGE TANK	10000.9	2931.0	25.000	1.200	0.000	16.0	250000.	0.	0.	0.	0.
COOLING TOWER	12000.5	3517.0	60.000	1.300	0.000	80.0	100000.	5000.	5000.	50000.	15000.
DIESEL GENERATOR	8499.6	2491.0	750.000	1.200	1.500	480.0	20000.	25000.	9000.	50000.	21000.
DOUBLE-BUNDLE CHILLER	12000.5	3517.0	180.000	1.300	0.000	500.0	100000.	20000.	5000.	50000.	15000.
GAS TURBINE	8499.6	2491.0	600.000	1.200	1.200	360.0	60000.	0.	0.	30000.	12000.
HEAT PUMP	12000.5	3517.0	180.000	1.200	0.000	500.0	100000.	20000.	5000.	50000.	15000.
HOT STORAGE TANK	10000.9	2931.0	10.000	1.200	0.000	16.0	250000.	0.	0.	0.	0.
ONE-STAGE ABSORBER	12000.5	3517.0	110.000	1.200	0.000	400.0	100000.	20000.	8000.	50000.	15000.
OPEN CHILLER	12000.5	3517.0	100.000	1.200	0.000	500.0	100000.	20000.	5000.	50000.	15000.
RECIPROCATING CHILLER	12000.5	3517.0	80.000	1.200	0.000	500.0	100000.	20000.	5000.	50000.	15000.
SOLAR COLLECTORS	32.3	3.0	.003	2.500	0.000	0.0	0.	0.	0.	0.	0.
STEAM TURBINE	8499.6	2491.0	450.000	1.300	1.000	300.0	200000.	0.	0.	40000.	20000.
TWO-STAGE ABSORBER	12000.5	3517.0	170.000	1.200	0.000	400.0	100000.	20000.	8000.	50000.	15000.
TWO-STAGE ABSORBER W/ECON	12000.5	3517.0	170.000	1.200	0.000	400.0	100000.	20000.	8000.	50000.	15000.

Note: Solar collector sizes are in sq ft and m^2, not in kBtu/h and kW.

Equipment Cost Logic

For each piece of equipment specified under the EQUIPMENT SELECTION block:

1. If ACTUAL EQUIPMENT COST data are specified for a given equipment type and size, that actual data will be used to compute costs.

2. For any equipment type and size for which ACTUAL EQUIPMENT COST data are not specified, either user-specified or default REFERENCE EQUIPMENT COST data are used according to the following cost scaling rules.

Cost scaling is used to adjust cost parameters for equipment whose size is different from the default or user-specified reference size.

Except for SIZE and INSTALLATION COST FACTOR, each of the parameters is assigned a value for the exponent, P, in the following scaling formula (see Figure 42):

$$\frac{CE}{CR} = \left(\frac{SE}{SR}\right)^P \qquad \text{[Eq 7]}$$

where: CE = one of the cost parameters
CR = corresponding reference cost
SE = size of equipment specified in EQUIPMENT SELECTION
SR = size of reference equipment
P = .67 for capital and overhaul costs
= .4 for consumables
= .1 for maintence hours and overhaul intervals
= .1 for equipment life.

Thus, from the example, equipment life for the 250 kBtu/hr (73 kW) gas turbine would be:

$$\frac{CE}{600000} = \left(\frac{250}{2491}\right)^{0.1} \qquad [Eq\ 8]$$

Therefore:

$$CE\ (\text{or LIFE}) = 476800. \qquad [Eq\ 9]$$

Other Cost Parameters

If desired, the original investment as well as annual and periodic costs for the building and/or the fan system may be stipulated. The format for this parameter block is:

Begins input data block

```
OTHER COST PARAMETERS:
    BUILDING CAPITAL COST = 0.0;
    ANNUAL BUILDING MAINTENANCE = 0.0;

    PERIODIC BUILDING COSTS = 0.0, PERIOD = 0.0;
    FAN SYSTEM CAPITAL COST = 0.0;
    ANNUAL FAN SYSTEM MAINTENANCE = 0.0;
    PERIODIC FAN SYSTEM COSTS = 0.0; PERIOD = 0.0;
END OTHER COST PARAMETERS;
```

Initial building cost in dollars. Considered one time in life-cycle costing.

Annual building maintenance cost in dollars per year. Applied every year and discounted in life-cycle costing.

Time in years between building refurbishings.

Cost in dollars for each building refurbishing. Accounted for in life-cycle costing in the years of occurrence.

Same as those above, but for fan system.

Ends input data block. END; is equivalent.

Some or all parameters may be entered.

Omitted parameters use default values, which are all zero.

Reports

The normal reports produced by a central plant simulation include a monthly energy demand and consumption summary, equipment use statistics, and life-cycle cost analysis results. The following paragraphs describe the energy demand and consumption summary report (Central Plant Energy Utilization Summary). This report is presented in 13 columns and provides the following (see Figure 43):

MONTH: The number of the month.

TOTAL HEAT ENERGY: The total heat energy demanded is the sum of the energy required for the fan system's hot water coils and the building's domestic hot water heating, plus the heat required to drive any absorption chillers and/or steam turbine generators.

TOTAL ELECTR ENERGY: Total electric energy consumed for the building, including that consumed for cooling.

COOLING ENERGY: Total cooling energy delivered to the building fan systems. This is the total chilled water demand.

RCVRED ENERGY: Waste heat from power-producing equipment and double-bundle chillers, and heat from solar collectors which has been usefully applied to meet heating and/or cooling demands. This energy offsets part or all of the energy requirements given in the Total Heat Energy column.

WASTED RCVRABLE ENERGY: Heat energy from the above sources which could have been recovered, but which was wasted due to lack of coincident demand (thermal storage can often reduce the amount of recoverable heat wasted).

HEAT EN INPUT COOLING: Fuel energy input to the central plant used to produce heat consumed for cooling (zero if absorbers are not used).

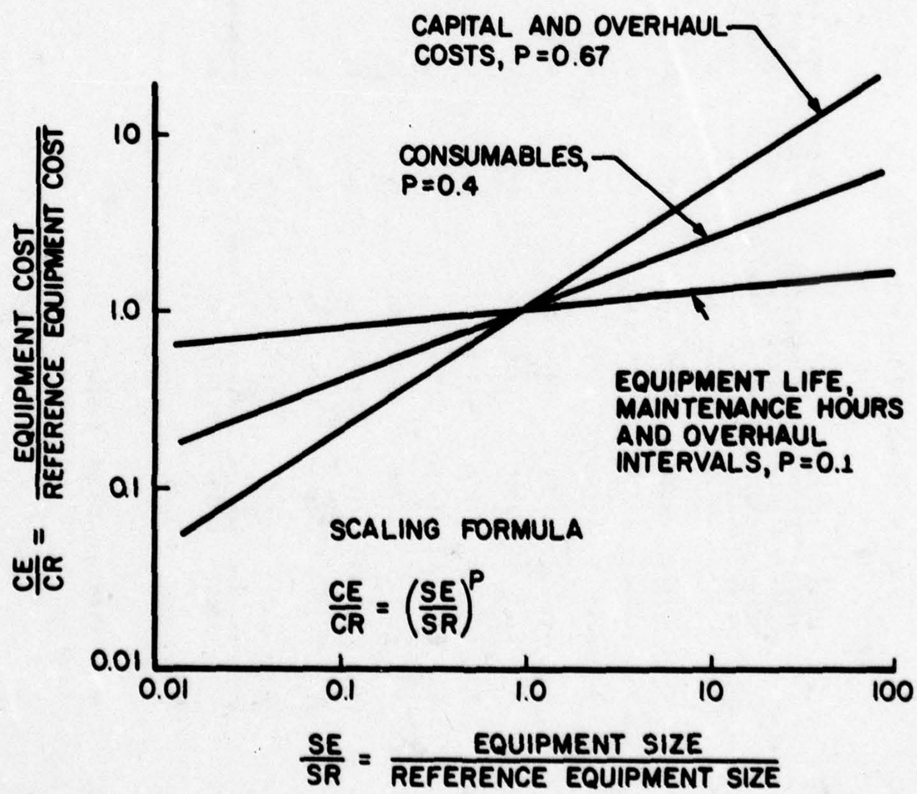

Figure 42. Cost scaling.

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C E N T R A L   P L A N T   E N E R G Y   U T I L I Z A T I O N   S U M M A R Y

MONTH	TOTAL HEAT ENERGY (GBTU)	TOTAL ELECTR ENERGY (GBTU)	COOLING ENERGY (GBTU)	RCVRED ENERGY (GBTU)	WASTED RCVRABL ENERGY (GBTU)	HEAT EN INPUT COOLING (GBTU)	ELEC EN INPUT COOLING (GBTU)	ENERGY INPUT HEATING (GBTU)	ENERGY INPUT ELECTRC (GBTU)	TOTAL FUEL INPUT (GBTU)	TOTAL ENERGY INPUT (GBTU)	AVERAGE PLANT EFFIC (PERCT)
1	.1487	.0863	.1068	0.	0.	0.	.0848	.2567	.2876	.2567	.5443	43.
2	.1393	.0761	.0900	0.	0.	0.	.0743	.2389	.2536	.2389	.4925	44.
3	.1382	.0871	.1209	0.	0.	0.	.0899	.2421	.2903	.2421	.5324	42.
4	0.	.0722	.0422	0.	0.	0.	.0621	0.	.2408	0.	.2408	30.
5	0.	.0786	.0726	0.	0.	0.	.0778	0.	.2620	0.	.2620	30.
6	0.	.0821	.1116	0.	0.	0.	.0891	0.	.2737	0.	.2737	30.
7	0.	.0878	.1342	0.	0.	0.	.0991	0.	.2927	0.	.2927	30.
8	0.	.0870	.1364	0.	0.	0.	.0999	0.	.2900	0.	.2900	30.
9	0.	.0788	.0852	0.	0.	0.	.0807	0.	.2626	0.	.2626	30.
10	.1049	.0953	.1729	0.	0.	0.	.1123	.1929	.3176	.1929	.5105	39.
11	.1217	.0814	.1247	0.	0.	0.	.0690	.2153	.2714	.2153	.4866	42.
12	.1479	.0865	.1077	0.	0.	0.	.0853	.2554	.2883	.2554	.5437	43.
	.8007	.9991	1.3052	0.	0.	0.	1.0444	1.4012	3.3304	1.4012	4.7316	36.

PLANT FOR BASIC SYSTEM

Figure 43. Central Plant Energy Utilization Summary.

ELEC EN INPUT COOLING: Fuel energy input used to produce electricity consumed for cooling, including fuel energy used to produce purchased power, if any. Purchased power is produced at the efficiency specified by the TOTUEF special parameter. This does not include chilled and condenser water pumping or cooling tower energy.

Energy Input Heating: Fuel energy input to the central plant that is used to produce heating. This includes boiler fuel and the fraction of diesel or gas turbine fuel which does not result in electric power. This does *not* include hot water pumping energy.

Energy Input Electric: Fuel energy input used to produce the electricity shown in the column labeled Total Electr Energy. This includes fuel energy used to produce purchased power, if any.

Total Fuel Input: Total fuel energy input to the central plant (boiler and/or engine fuel energy). This does not include purchased power or the fuel used to make purchased power.

Total Energy Input: Total energy input, including fuel required to produce purchased power, if any.

Average Plant Efficiency: The sum of **Total Heat Energy** and Total Elect Energy divided by Total Energy Input. (This number may not be meaningful if equipment does not meet demands.)

The Equipment Use Statistics report (see Figure 44) shows the average operating ratio, peak demand, and first occurrence of the peak shown for each equipment type. Operating hours are shown for each size of equipment. If more than one piece of equipment of a given size is selected, *this number* is the sum of the operating hours for all units of the given size. First year energy consumption and cost are also shown.

The Life-Cycle Cost Summary reports the annual contribution to total life-cycle cost of capital, annual, and periodic costs for buildings, fan systems, and central plants and annual energy cost (see Figure 45).

Specifying

EQUIPMENT PARAMETERS

as a **REPORTS** parameter (see **RUN CONTROL**, Chapter 3), causes a more detailed report to be printed showing default and user-supplied **SPECIAL PARAMETERS, EQUIPMENT PERFORMANCE PARAMETERS, REFERENCE,** and **ACTUAL EQUIPMENT COST, EQUIPMENT ASSIGNMENT** tables, and **LIFE CYCLE COST** and **ENERGY COST** parameters.

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E Q U I P M E N T   U S E   S T A T I S T I C S

EQUIPMENT	AVG OPER RATIO	MAX LOAD (KBTUH)	MON	DAY	HR	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS
STEAM BOILER	.230	298.9	1	13	6	800.0	4344								
HERMETIC COMPRESSION CHILLER	.252	428.2	10	10	14	600.0	8640								

UTILITY, ENERGY	1YR UNADJ COST (K$)	1-YEAR USAGE (GBTU)	PEAK USAGE (KBTUH)	COST ESCALATION FACTOR
ELECT	12.5	.999	242.5	0.
BOILER	2.1	1.401	476.5	0.
UTILITY, ENERGY TOTAL	14.6			

Figure 44. Equipment Use Statistics report.

```
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          L I F E   C Y C L E   C O S T   S U M M A R Y        (ALL COSTS IN DOLLARS)

***ADJUSTED PRESENT WORTH OF ANNUAL AND PERIODICALLY RECURRING COSTS   (ADJUSTMENT FACTOR =  1.000)***
```

YEAR	BUILDING ANNUAL COSTS	BUILDING PERIODIC COSTS	FAN SYSTEM ANNUAL COSTS	FAN SYSTEM PERIODIC COSTS	CENTRAL PLANT ANNUAL COSTS	CENTRAL PLANT PERIODIC COSTS	FUEL AND UTILITIES ELECTRIC POWER	FUEL AND UTILITIES BOILER FUEL	FUEL AND UTILITIES DIESEL FUEL	FUEL AND UTILITIES GAS TURBINE FUEL	TOTAL
1					13083		12343	2081			27507
2					11894	708	12006	2043			26651
3					10813		11678	2006			24497
4					9830	585	11360	1970			23745
5					8936	1405	11050	1934			23325
6					8124	397	10749	1899			21169
7					7385	439	10456	1864			20144
8					6714	960	10170	1830			19674
9					6103	7168	9893	1797			24961
10					5548	58	9623	1764			16993
11					5044	299	9361	1732			16436
12					4585		9105	1701			15391
13					4168	860	8857	1670			15555
14					3789	185	8616	1639			14229
15					3445	36	8381	1610			13472
16					3132	600	8152	1580			13464
17					2847		7930	1552			12329
18					2588	2507	7713	1523			14331
19					2353	139	7503	1496			11491
20					2139		7298	1468			10905
21					1944	115	7099	1442			10600
22					1768	199	6906	1416			10289
23					1607	78	6717	1390			9792
24					1461	33	6534	1365			9393
25					1328		6356	1340			9024
	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
TOTAL					130628	16771	225856	42112			415367

Figure 45. Life Cycle Cost Summary report.

```
CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0            16 MAY 79      06.54.13

   ***CAPITAL COSTS***
      BUILDING                  0.             T O T A L   L I F E   C Y C L E   C O S T
      FAN SYSTEM                0.             ****************************************
      CENTRAL PLANT         46648.             ***           $  462015.             ***
                          --------             ****************************************
   TOTAL CAPITAL COST       46648.
   TOTAL ANN./PERIODIC      415367
```

Figure 45. (cont'd)

7 PERFORMING BUILDING ENERGY ANALYSES WITH BLAST

Introduction

The previous six chapters explained how to prepare an input deck and execute the BLAST program. This chapter describes systematic procedures for exercising the BLAST program to obtain and analyze expected building energy consumption. The emphasis is on using procedures that will consider both construction and energy costs in determining the most economical building design.

While BLAST provides valuable assistance in performing calculations required to design heating, ventilating and air-conditioning systems and select equipment, it is most useful as a tool to evaluate design alternatives. The steps listed below are required to evaluate design alternatives and will help assure that the final design is energy-conservative:

1. Establish a baseline design for the building, fan system, and central plant (with the assistance of the BLAST program, as appropriate). For an existing building, this will be the as-built condition of the building.

2. Use BLAST to simulate the baseline building.

3. Evaluate the design by carefully inspecting and plotting (as appropriate) the results of the baseline simulation (evaluation criteria are suggested in the **Design Evaluation Criteria** section of this chapter).

4. Redesign the building and its energy systems to make it more energy-conservative based on the results of the evaluation.

5. Use BLAST to simulate the redesigned building, fan system, and central plant.

6. Repeat steps 3 through 5 until the "best" building, fan system, and central plant have been determined.

This iterative approach to design, made possible by computerized energy calculation procedures, represents a new opportunity to optimize the design of buildings and energy systems; however, the analysis procedure is not automatic and considerable judgment, intuition, and analysis by the designer are still required.

In the sections that follow, some of the factors that affect building energy use are outlined and procedures are suggested for performing an evaluation of candidate designs, using the results of a BLAST simulation. The procedures are illustrated with a complete case study. Although not discussed, building codes, functional requirements, aesthetics, and other mandatory requirements or regulations must always be considered in evaluating alternate designs.

Factors Affecting Building Energy Use

The BLAST program performs its energy analysis of a building and its systems by (1) calculating loads, (2) simulating air distribution systems, and (3) simulating the central plant. Often, the design of a building follows this same approach; i.e., (1) the building shell is designed, (2) fan systems are designed, (3) central plant components are selected. However, in the course of evaluating

building designs, loads, air distribution systems, and central plant equipment performance are inextricably interrelated. To make the design evaluation process manageable, each of these factors is examined separately, remembering that interrelationships exist: the case study that follows illustrates how these interrelationships can be reasonably evaluated.

The following outline summarizes the design variables as they affect each design phase:

1. Loads
   a. Building construction
   b. Room temperature control
2. Air distribution system demand
   a. System type
   b. System size
   c. System control
3. Central Plant
   a. Component selection
   b. Component size
   c. Plant control

Heating and cooling loads in the building are influenced by two major classes of design variables: (1) building construction and (2) room temperature control. The level of insulation, the amount of mass in the construction materials used, the amount of glass and shading provided, and the lighting level are all examples of the type of construction variables that influence the heating and cooling loads to be met by a building's air distribution system. Room temperature control is often equally or more important, since it influences the amount of heat which can be stored in building materials, the amount of heating or cooling which can be avoided by allowing the room temperature to float and allowing nighttime cooldown of buildings during the air-conditioning season, and by minimizing temperature gradients between the outside and inside of the room over which heat transfer takes place.

Air distribution systems are affected by three classes of system design variables: (1) system type, (2) system size, and (3) system control. The type of air distribution system selected has a major impact on the amount of energy required to meet space heating and cooling loads. For example, multizone and reheat systems usually require more energy than variable volume or fan coil systems to meet the same heating and cooling loads. The type of system selected determines the room temperature control options available to the designer, and whether or not economy cycles can be used to offset part of the chilled water demand. The size of a system is also an important and often overlooked design parameter. It is often particularly critical to good performance that the air distribution system be sized accurately. An oversized system often has little opportunity to perform efficiently, and an undersized system will frequently be unable to maintain desired comfort condi-

tions. System control is another important parameter. The amount of outdoor air introduced, the type of economy cycle employed, the method for controlling hot and cold deck temperatures and air stream volumes, and the methods for cycling the fan when it is not required all greatly affect energy use. These effects are not always intuitive. For example, economy cycles can increase rather than decrease energy consumption.

Three classes of central plant variables affect energy use: (1) component selection (this defines the configuration of the central plant), (2) component size, and (3) central plant control. When thoroughly analyzing a building design, it should be noted that the number, type, and size of components selected to meet the hot and chilled water demands of air distribution systems are equally important. An inefficient central plant nullifies the effects of a well-designed building and air distribution system. For example, selecting a single large chiller for a building which experiences extreme variations in air-conditioning load might cause the chiller to run routinely under very low part-load operating conditions. Since chillers and most other central plant components perform less efficiently under a low part-load ratio, such a design decision almost invariably leads to higher-than-necessary energy use. Plant control strategies go with effective component selection. For example, it is important to insure that the right chiller among several chillers of differing sizes is running in the right load range. Similarly, if several different types of chilling equipment (such as heat pumps, double-bundle chillers, or absorption chillers) are used, it is important to be sure that the plant is controlled so that the most efficient device is used to meet the demands in any one hour.

Design Evaluation Criteria

Table 14 has been constructed to provide a checklist for evaluating each candidate design as it is simulated using the BLAST program. This table provides the designer with some (but not necessarily all) criteria for evaluating each design as he/she examines the results of the BLAST design simulation. The table is intended to serve two functions: first, it is a checklist, and second, it offers some brief instructions and guidance about methods for improving any design inadequacies. However, the user should note that this checklist is no substitute for good engineering judgment, and it cannot possibly be inclusive, given the wide range of available system and building design opportunities. Furthermore, the list does not contain functional, site, or mission considerations which may preclude many options. However, after completing a design by the iterative procedure described in the introduction of this chapter, if favorable responses can be offered to each of the evaluation questions posed in Table 14, the design will probably be a good one.

In evaluating designs, it is often useful to apply Table 14 when comparing various design options. Obviously, when the baseline design is being evaluated, such a comparison opportunity does not exist; however, once the baseline has been evaluated and a preferred alternative is simulated, such questions as the reasonableness of the peak loads, whether peaks and valleys are extreme, and whether monthly heating and cooling loads are reasonable, can often be better determined by comparing the baseline with a more energy-conservative option.

A Case Study

To illustrate the application of BLAST, a building energy analysis was performed for a dental clinic in Texas. This section summarizes the highlights of this analysis.

The dental clinic is a one-story building of approximately 9000 sq ft (810 m^2) constructed of concrete block and brick, with a flat built-up roof and approximately 15 percent glass area evenly distributed around the building. Figure 46 shows a plan of the building, and Figure 47 shows typical

Table 14
Evaluation Criteria

1. LOADS

A. Design Day Results (plot loads vs time of day)

(1) Are hourly and peak loads reasonable (based on experience)? ____

(2) Are there extreme peaks and valleys in the daily load profiles? ____

(If yes, adding mass to the building inside the insulation may smooth the profile. Morning cooling loads can be reduced by reducing east-facing glass areas, afternoon loads can be reduced by reducing west-facing glass.)

(3) Are peak loads occuring late in the afternoon just before the building is vacated for the day? ____

(If yes, consider adding mass to shift the peak to an unoccupied period when equipment is off.)

(4) Are peak loads resulting from morning warmup or cooldown? ____

(If yes, consider sizing for peaks that occur later in the day and starting one hour earlier in the morning.)

(5) Are lighting loads a major fraction of the cooling load? ____

(If yes, consider *adding* glass and removing lights, provided that heating load increases are not too severe. Consider providing task lighting and reducing general lighting levels.)

(6) Do some zones require heating at the same time others require cooling? ____

(If so, consider using separate systems to serve each type of zone.)

B. Annual Results (plot the monthly heating and cooling loads)

(1) Are cooling loads in winter significant? ____

(If so, consider using an economy cycle when selecting fan system control strategies.)

(2) If heating and/or cooling is off at night or on weekends, are maximum and minimum zone temperatures acceptable? ____

(If no, consider temperature setback rather than complete system shutoff to avoid extremely high or low temperatures in the zones.)

Table 14 (Cont'd)

2. SYSTEMS

A. Design Day Results

(1) Is peak heating or cooling coil demand much higher than the average for the period when the fan system is operating? ____

(If yes, consider reducing outside air for peak hours.)

(2) Are heating and cooling coils demanding energy simultaneously? ____

(If yes, consider a different type of system or put different zones with better load-matching on the system. Consider possible cold and/or hot deck reset control. For multizone or three-deck multizone, an economy cycle may cause heating coil demands, even when there are no zone heating loads.)

(3) Is fan power consumption acceptable? ____

(If no, look for ways to reduce total fan pressure or select more efficient fans.)

(4) Are there any unmet loads? ____

(If yes, check cold and/or hot deck control scheme and fan and coil schedules to be sure that they are consistent with room temperature control strategies. Check supply air volumes to the zone.)

B. Annual Results (plot monthly heating and cooling coil demand)

(1) Are monthly cooling energy and heating energy requirements consistent with the sum of the monthly heating and cooling loads? ____

(If no, the cause is usually outdoor air cooling and heating or battling of the heating and cooling coils. Consider any or all of the following:

(a) Reducing outdoor air

(b) Changing systems

(c) Implementing hot and cold deck reset control)

(2) Is cooling coil demand limited mainly to summer months, and is heating coil demand limited mainly to winter months? ____

(If no, consider an economy cycle if not already specified. Consider hot and/or cold deck reset [reducing minimum variable air volume (VAV) fraction may also help, if VAV is specified]. Or consider a different type of system.)

Table 14 (Cont'd)

3. CENTRAL PLANT

A. Design Days

(1) Is peak demand consistent with selected equipment capacity? ____

(If no, consider different equipment sizes.)

(2) Is equipment average part-load ratio relatively high (on summer design days for chillers and winter design days for boilers)? ____

(If not, consider more pieces of smaller equipment, or, if multiple sizes have been specified, consider a different operating strategy. If average part-load ratios are low for design days, they will be even lower for the annual period.)

B. Annual Results

(1) Are equipment efficiencies and COPs satisfactory? ____

(If not, the cause may be poor average part-load ratio [equipment running much of the time at a small fraction of its capacity]. More units of smaller size should be considered.)

(2) Looking also at the sum of zone cooling loads, are there substantial summer cooling loads, and are annual heating costs simultaneously high? ____

(If yes, consider using a heat pump or double-bundle chiller and eliminating the economy cycles on one or more systems served by the central plant [if economy cycles were simulated].)

(3) Does annual energy use meet the building energy budget or performance standard? ____

(If no, separately examine the components of building energy use [i.e., lights, fan power, heating and cooling loads, heating and cooling coil demand, chiller and boiler energy consumption]. Re-evaluate the building and energy system design, looking for ways to reduce energy. Examining each energy use component should reveal the part or parts of the design which have led to excessive energy use.)

(4) Is solar heating a viable option? ____

(Use CERL Technical Report E-139/ADA 062719, *Design of Solar Heating and Cooling Systems*, to make a preliminary analysis of solar energy as a heating and/or cooling energy source. The needed heating and cooling energy demands can be taken directly from the central plant energy-use summary produced by BLAST. If the preliminary analysis is favorable, simulate several solar energy systems, using BLAST to determine the system life-cycle cost [this cost is calculated in the course of the BLAST simulation]. Compare the life-cycle cost of the best solar design with the best conventional design in order to make the final decision.)

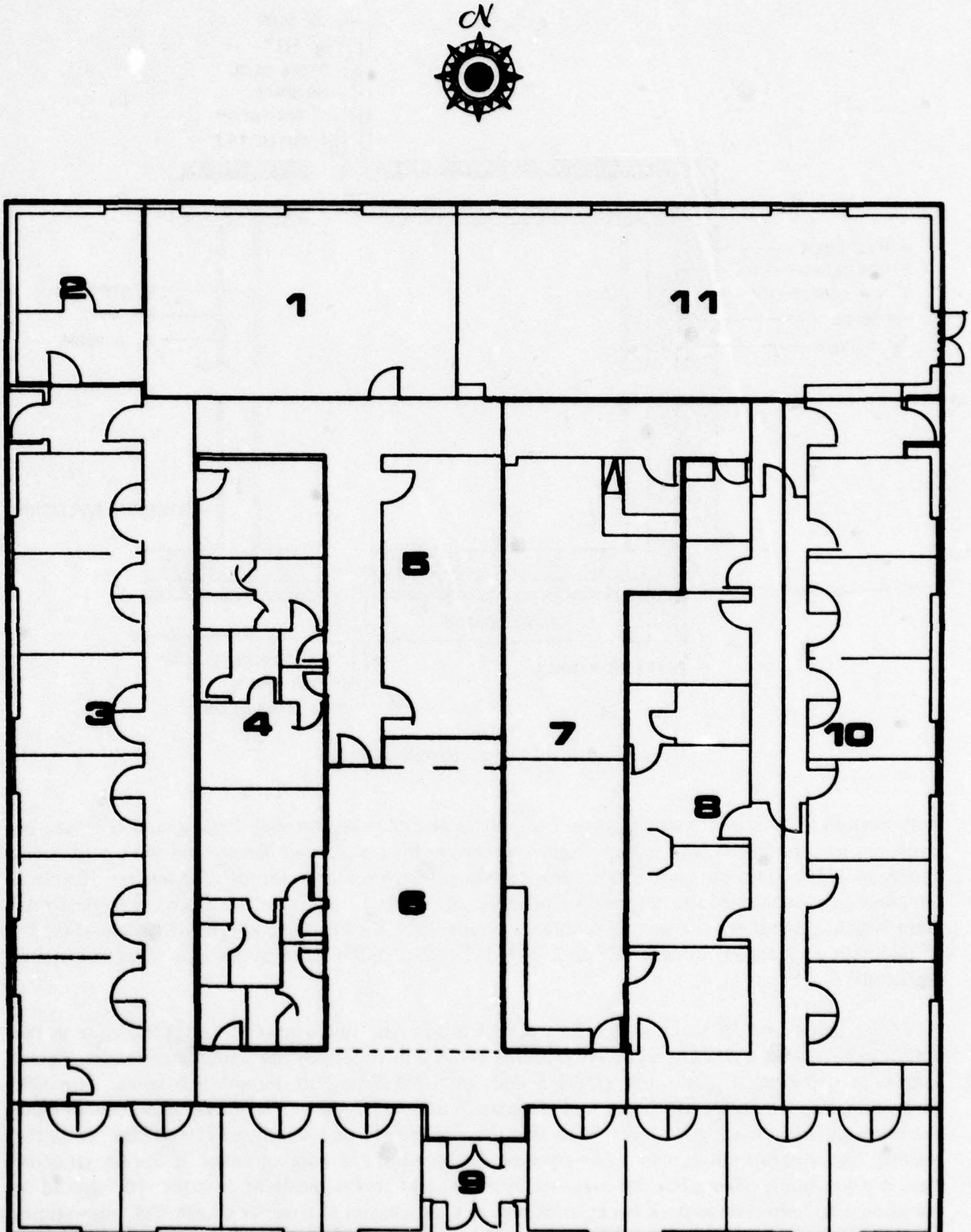

Figure 46. Plan of Dental Clinic.

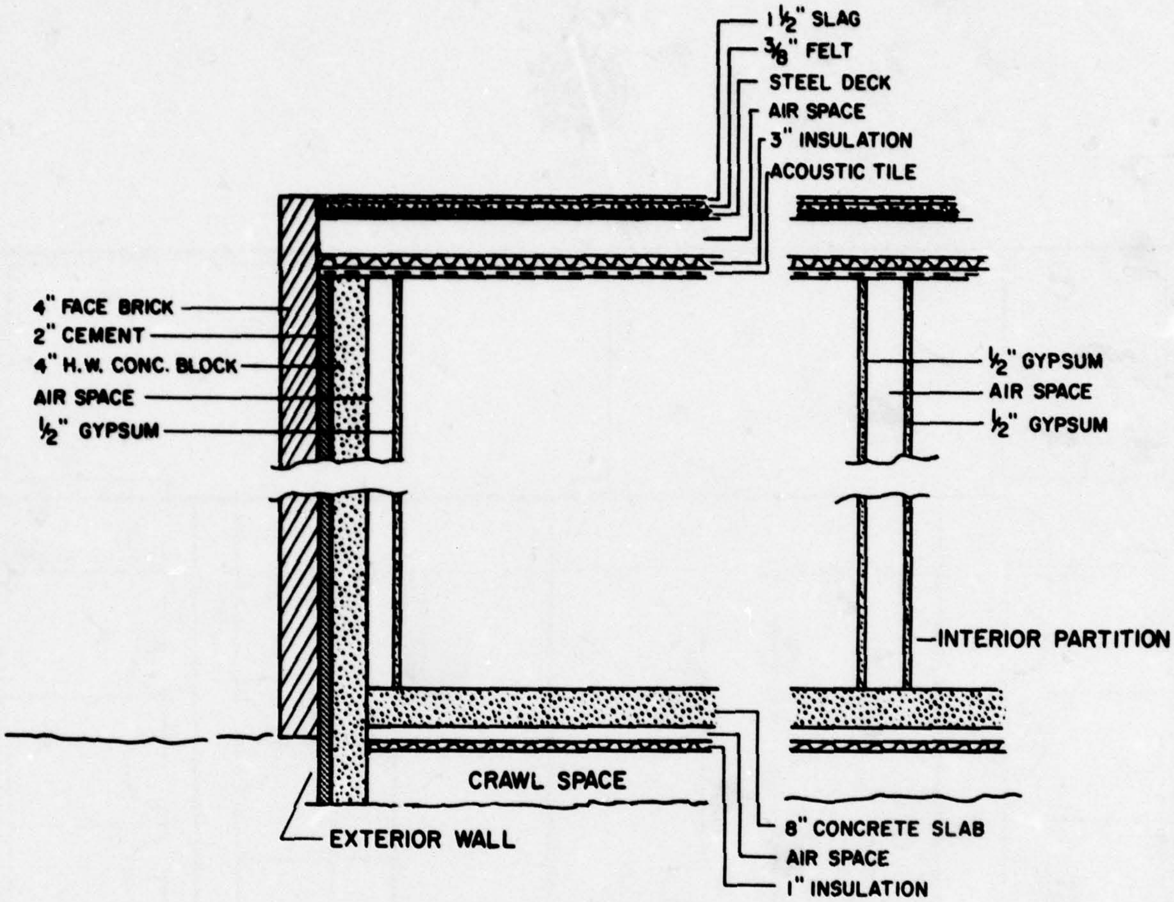

Figure 47. Typical wall sections.

wall sections. The clinic operates from 7 am to 5 pm, Monday through Friday, and is closed on weekends and holidays. The system used is a conventional multizone fan system with cold decks energized year round, but with a hot deck de-energized from March through September. Hot deck temperature is scheduled on the basis of outdoor air. Table 15 is a printout from the BLAST program which summarizes the system features. As operated, the heating and cooling system attempts to maintain each space between 68° and 70°F (19.8 and 20.9°C) year round (including nights and weekends).

Figures 48 and 49 show design day plots for summer and winter for a typical zone in the building. Note that there are relatively extreme peaks and valleys in the design day results. This is somewhat unexpected, since the exterior walls of the building are relatively massive. However, an examination of Figure 46 shows that the mass is in the outside wall layers and is separated from the room by an insulating air layer. With this mass helping to dampen the effects of climate on the cooling load, interior equipment loads are now the cause of the cooling peaks. If the dental clinic were not yet built, adding interior mass to partitions and to the inside of exterior walls should be considered to help reduce peak loads. Although not shown, on the winter design day, some zones require heating while others require cooling. This suggests that a multizone system may not be appropriate for this building, or that interior zones should be cooled by a system which is separate from the one serving exterior zones.

Table 15
Baseline Fan System Description

```
 CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0                 28 MAR 79       18.17.13

 ************************************************************************
 *                                                                      *
 *   A I R   H A N D L I N G   S Y S T E M   D E S C R I P T I O N      *
 *                                                                      *
 ************************************************************************


                 MAIN

SYSTEM NUMBER =           72              SYSTEM LOCATION =  13983

SIM. PERIOD =  1JAN1968 - 31DEC1968       NO. OF DAYS IN SIMULATION =  366

TYPE SYS = MULTIZONE                      NO. DISTINCT ZONES ON SYS. =     4


SYSTEM OPERATION = CONTINUOUS

                SEASONAL COMPONENT SCHEDULES
PREHEAT COIL          ON -  1JAN           OFF - 31DEC
HEATING COIL          ON -  1JAN           OFF - 31DEC
COOLING COIL          ON -  1JAN           OFF - 31DEC
HEATREC COIL          ON -  0JAN           OFF -  0JAN

           DAILY PREHEAT COIL SCHEDULE                 T = ON , F = OFF
HOUR   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
WKDAY  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T
WKEND  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T

           DAILY HEATING COIL SCHEDULE                 T = ON , F = OFF
HOUR   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
WKDAY  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T
WKEND  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T

           DAILY COOLING COIL SCHEDULE                 T = ON , F = OFF
HOUR   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
WKDAY  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T
WKEND  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T

           DAILY HEATREC COIL SCHEDULE                 T = ON , F = OFF
HOUR   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
WKDAY  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T
WKEND  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T  T


TOTAL SUPPLY  FAN PRESSURE =      2.48914      IN-H20
TOTAL RETURN  FAN PRESSURE =      0.           IN-H20
TOTAL EXHAUST FAN PRESSURE =      1.00369      IN-H20


SUPPLY  FAN EFFICIENCY =     .70
RETURN  FAN EFFICIENCY =     .70
EXHAUST FAN EFFICIENCY =     .70

MIXED AIR CONTROL = FIXED PERCENT
DESIRED MIXED AIR TEMPERATURE = COLD DECK TEMP
```

Table 15 (Cont'd)

DAILY VENTIALTION PROFILES

HOUR	1	2	3	4	5	6	7	8	9	10	11	12
WKDAY MIN	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
WKDAY MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	13	14	15	16	17	18	19	20	21	22	23	24
WKDAY MIN	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
WKDAY MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	1	2	3	4	5	6	7	8	9	10	11	12
WKEND MIN	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
WKEND MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOUR	13	14	15	16	17	18	19	20	21	22	23	24
WKEND MIN	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
WKEND MAX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

HOT DECK CONTROL = FIXED SET POINT
HOT DECK THROTTLING RANGE = 7.20000 DEG. F
HOT DECK FIXED TEMPERATURE = 140.00000 DEG. F

HEATING COIL CAPACITY = .341E+07 1000BTU/HR
HEATING COIL ENERGY SUPPLY = HOT WATER

COLD DEC CONTROL = FIXED SET POINT
COLD DEC THROTTLING RANGE = 7.20000 DEG. F
COLD DEC FIXED TEMPERATURE = 55.04000 DEG. F

ZONE DATA SUMMARY

ZONE NUMBER	ZONE SUPPLY AIR VOL	ZONE EXHAUST AIR VOL	ZONE REHEAT CAPCTY	ZONE REHEAT ENERGY	ZONE TSTAT BB CAPCTY	ZONE TSTAT BB ENERGY	ZONE MULT
1	5.000E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
2	5.000E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
3	5.000E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0
4	5.000E+02	0.	0.	HOT WATER	0.	HOT WATER	1.0

TOTAL DESIGN SUPPLY AIR VOLUME = 2.000E+03

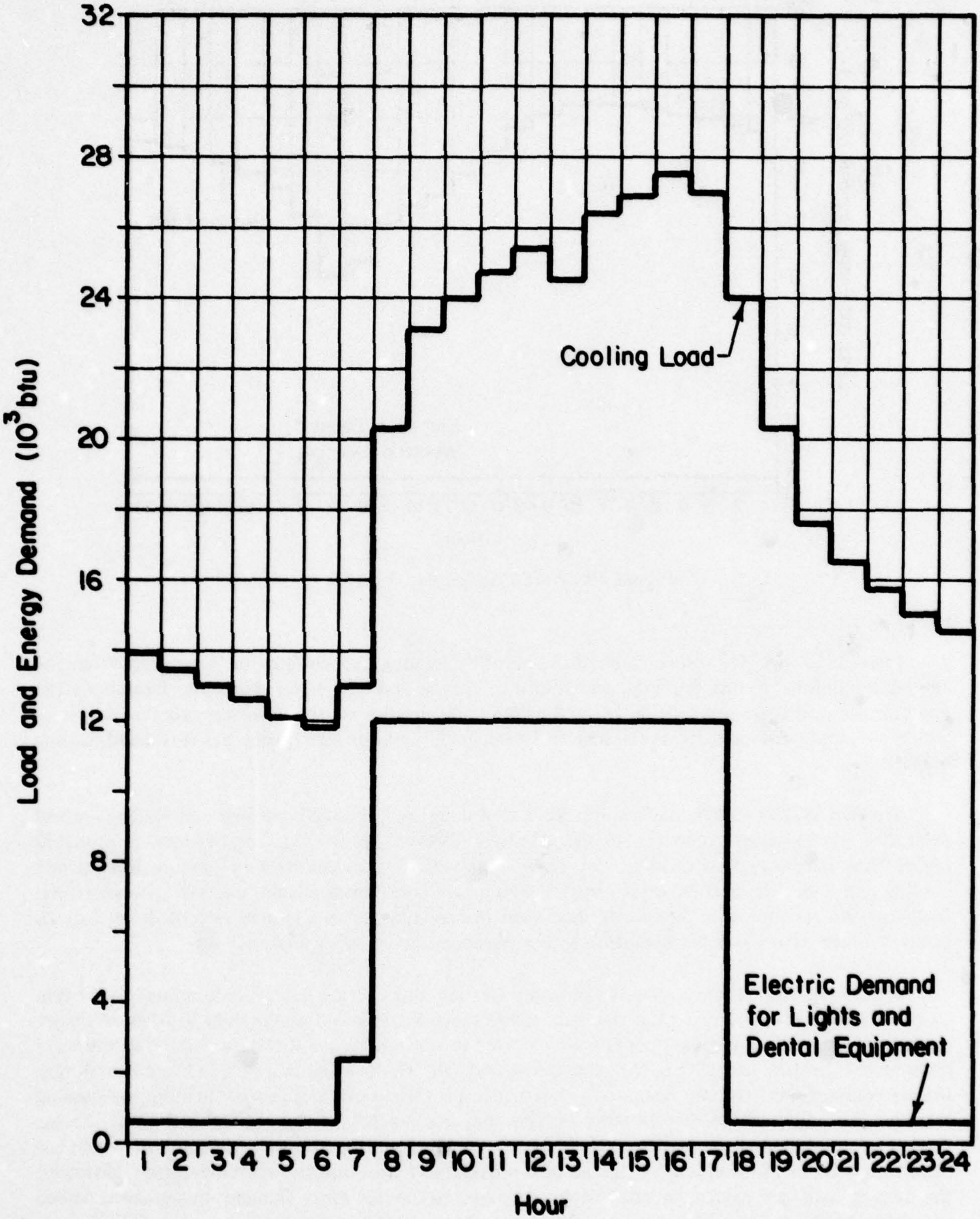

Figure 48. Summer design day, baseline.

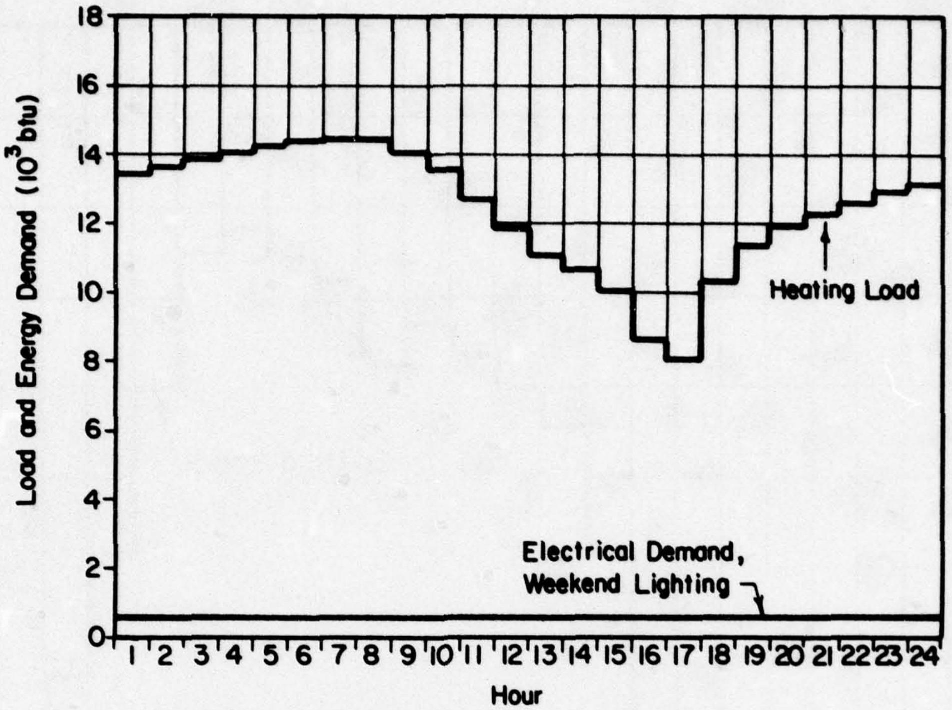

Figure 49. Winter design day, baseline.

Figures 50 and 51, respectively, show monthly heating and cooling loads resulting from the annual simulation of this building, and monthly chilled and hot water demands. Examining the loads shows that there are substantial cooling loads during the winter. This suggests that a system which can apply an economy cycle efficiently might be appropriate. Notice the very small heating loads.

The fan system design day results were examined and the peak cooling coil loads were not excessively large when compared to the average; however, the average cooling load is probably higher than necessary. Also, design day results show that there can be simultaneous heating and cooling coil demands, particularly in winter. Fan power consumption is not excessive; however, the fact that the fan operates 24 hours a day, even though the building is only occupied for 9 or 10 hours, suggests time clock fan operation as a possible conservation alternative.

Figures 50 and 51 show that the monthly heating and cooling energy requirements are often an order of magnitude larger than the sum of the space heating and cooling loads. Also, there are periods when both heating and cooling are required in substantial quantities; in particular, there are considerable heating coil demands in the spring and fall. The heating coil demands are zero during the six summer months only because the heating coil is turned off. Outdoor air heating and cooling account for only part of this extreme heating and cooling coil energy demand. Another factor typical of multizone systems is the battling of the heating and cooling system, some of which has been mitigated in this building by the use of hot deck reset with outdoor air temperature. However, the heating loads are extremely small when compared to the hot water demand; this suggests a need for changing the operating strategy and/or system design (notice particularly how the chilled water demand drops dramatically in April when the heating coil is de-energized).

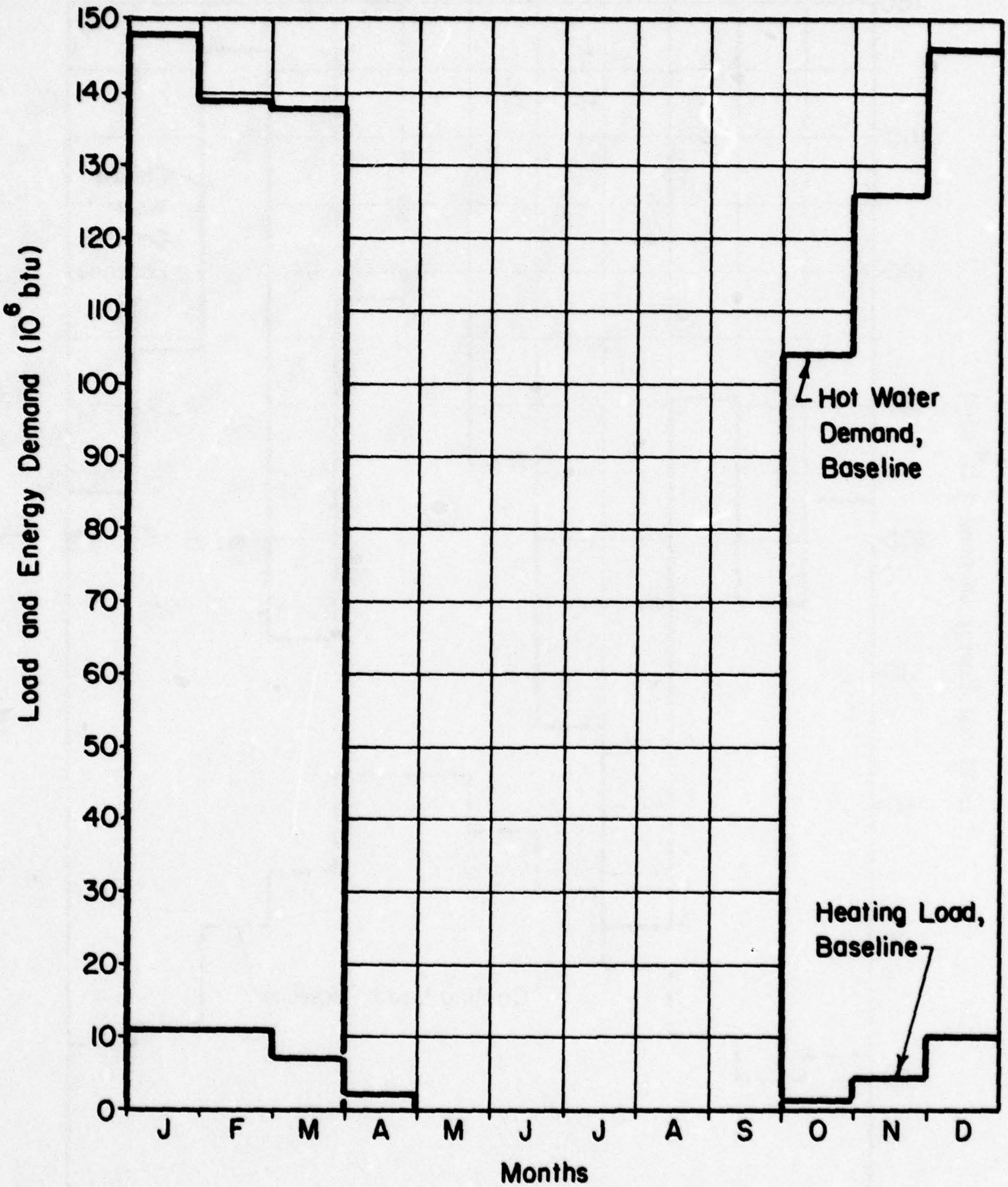

Figure 50. Monthly heating loads and hot water demand, baseline.

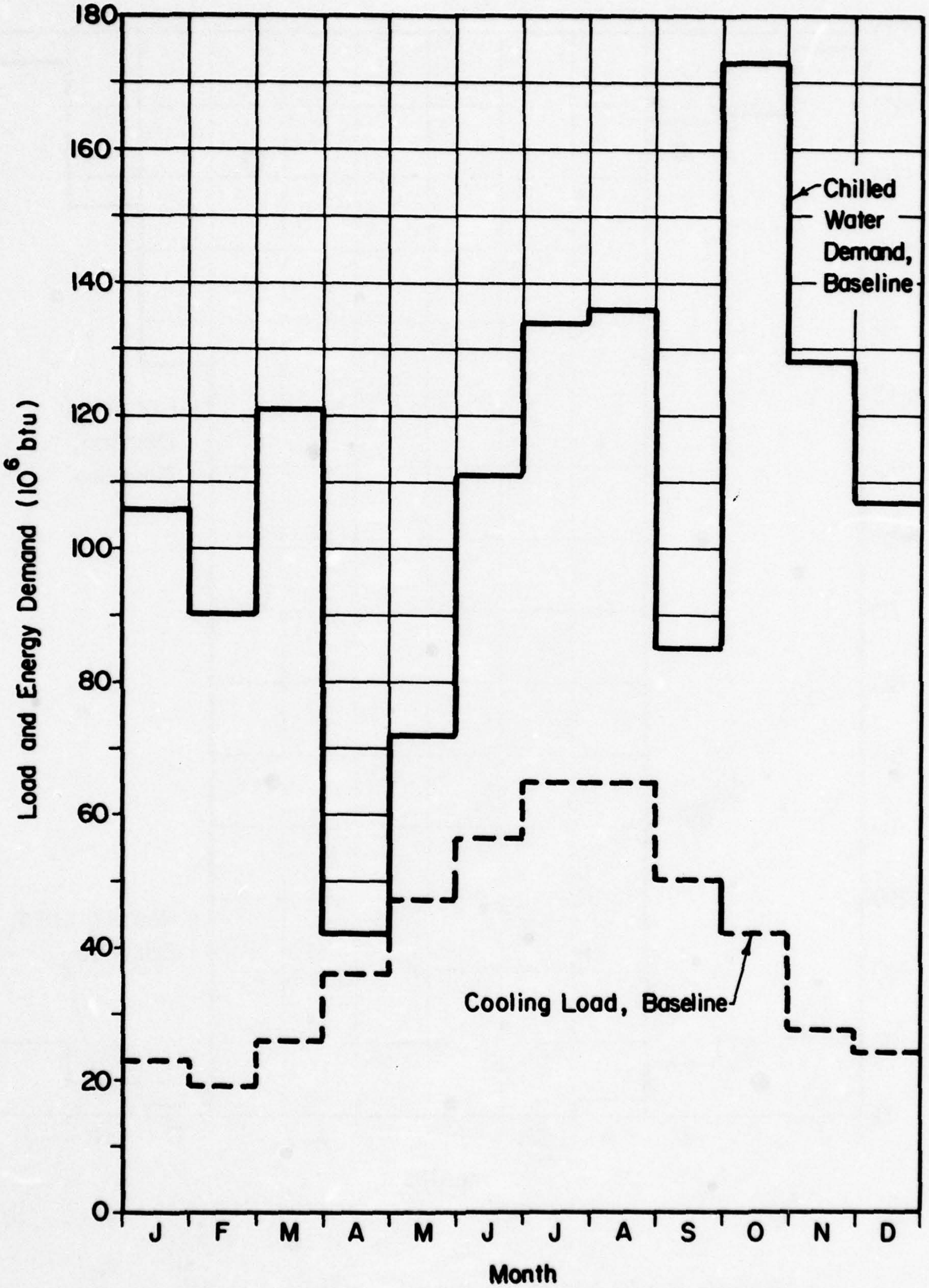

Figure 51. Monthly cooling loads and chilled water demand, baseline.

Figure 52 shows the central plant energy-use summary and equipment-use statistics produced by the BLAST program. From this summary, the boiler efficiency and coefficient of performance for the chiller were determined as shown in the figure. The COP for the chiller was approximately 4.2, which is somewhat lower than the COP reported in the manufacturer's catalog for this unit at peak capacity. Notice also that the average part-load ratio is rather low. This suggests that the chiller is frequently operating under very poor part-load conditions; in addition, based on a peak demand, the chiller appears to be somewhat oversized when compared to the capacity originally selected for installation in the building. A heat pump does not appear to be appropriate in this case because of the relatively small demand for heating in the space (based on the assumption that hot water demand can be substantially reduced by changes in the fan system). The estimated energy consumption for the baseline building is approximately 264 000 Btu/sq ft/year (77 373 kW/m^2/year).

One of the most obvious energy conservation alternatives for this building is to de-energize the fan system at night, on weekends, and on holidays. This was the first option simulated using the BLAST program (referred to as Option 1). Figure 53 shows a summer design day for this option. Notice that shutting the fan system off at night produces rather sizable morning cooldown loads; however, afternoon peak loads are still more severe. Also, in this case, since the fan system already exists, and unless total replacement of the fan system is intended, there is sufficient coil capacity to handle the cooldown loads. In Figure 53, the total demand for cooling on the design day is considerably lower than in the baseline case, even though cooling loads for Option 1 are higher than the baseline during the occupied period.

Figures 54 and 55 compare the loads in the building for the baseline case with the loads in the building when the system is shut off at night and on weekends (Option 1). Heating is also off from March through October. Notice that both heating and cooling are reduced considerably when the fan is shut off at night and on weekends.

Figures 56 and 57 compare the hot water and chilled water demands for Option 1 with baseline system demands. The extreme reduction in chilled and hot water demands is caused by three factors: (1) the load is substantially reduced by shutting the fan off at night and on weekends; (2) since the fan is shut off at night and on weekends, outdoor air heating and cooling is not accomplished during these time periods (in the hot Texas climate, this has a substantial effect on the demand for chilled water); and (3) battling of the hot and cold deck, which is typically worse during periods of low loads (at night and on weekends), cannot occur when the fan is off.

In examining the central plant report for Option 1 (not shown), it was determined that the chiller's coefficient of performance had improved slightly (to 4.6). This somewhat surprising result occurs because the chiller is not operating on nights and weekends when the demand for chilled water was minimal. Hence, the chiller not only operates many fewer hours, but when it does operate, it is slightly more efficient. However, boiler efficiency is not improved. The energy performance of the building operating under Option 1 is 94 000 Btu/sq ft/year (27.549 kWh/m^2-year).

Given that some simultaneous heating and cooling remained characteristic of Option 1, Option 2 dealt with the effects of resetting the hot and cold deck based on the zone requiring the most heating or cooling. This option is intended to minimize the battling between the hot and cold air streams typical of a multizone system. Note, however, that interior spaces in this building demand almost continuous cooling, while exterior spaces have some winter heating demand. Consequently, the cold deck usually cannot drift upward toward the room temperature, because interior zones require relatively cold air. However, Figures 58 and 59 show that there is some reduction in chilled and hot water demand. Since hot and cold deck reset, like time clock control of the fan system, is a fairly inexpensive conservation option, both Option 1 and Option 2 appear to be extremely viable economically.

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0 16 MAY 79 06.54.13

C E N T R A L   P L A N T   E N E R G Y   U T I L I Z A T I O N   S U M M A R Y

MONTH	TOTAL HEAT ENERGY (GBTU)	TOTAL ELECTR ENERGY (GBTU)	COOLING ENERGY (GBTU)	RCVRED ENERGY (GBTU)	WASTED RCVRABL ENERGY (GBTU)	HEAT EN INPUT COOLING (GBTU)	ELEC EN INPUT COOLING (GBTU)	ENERGY INPUT HEATING (GBTU)	ENERGY INPUT ELECTRC (GBTU)	TOTAL FUEL INPUT (GBTU)	TOTAL ENERGY INPUT (GBTU)	AVERAGE PLANT EFFIC (PERCT)
1	.1487	.0863	.1068	0.	0.	0.	.0848	.2567	.2876	.2567	.5443	43.
2	.[illegible]93	.0761	.0900	0.	0.	0.	.0743	.2389	.2536	.2389	.4925	44.
3	.1382	.0871	.1209	0.	0.	0.	.0899	.2421	.2903	.2421	.5324	42.
4	0.	.0722	.0422	0.	0.	0.	.0621	0.	.2408	0.	.2408	30.
5	0.	.0786	.0726	0.	0.	0.	.0778	0.	.2620	0.	.2620	30.
6	0.	.0821	.1116	0.	0.	0.	.0891	0.	.2737	0.	.2737	30.
7	0.	.0878	.1342	0.	0.	0.	.0991	0.	.2927	0.	.2927	30.
8	0.	.0870	.1364	0.	0.	0.	.0999	0.	.2900	0.	.2900	30.
9	0.	.0788	.0852	0.	0.	0.	.0807	0.	.2626	0.	.2626	30.
10	.1049	.0953	.1729	0.	0.	0.	.1123	.1929	.3176	.1929	.5105	39.
11	.1217	.0814	.1247	0.	0.	0.	.0890	.2153	.2714	.2153	.4866	42.
12	.1479	.0865	.1077	0.	0.	0.	.0853	.2554	.2883	.2554	.5437	43.
	.8007	.9991	1.3052	0.	0.	0.	1.0444	1.4012	3.3304	1.4012	4.7316	36.

$$\text{COP} = \frac{\text{COOLING ENERGY}}{\text{ELEC EN INPUT COOLING * TOTUEF}} = \frac{1.3052}{1.044 * .3} = 4.17$$

$$\text{BOILER EFFICIENCY} = \frac{\text{TOTAL HEAT ENERGY}}{\text{ENERGY INPUT HEATING}} = \frac{.8007}{1.4012} = .57$$

$$\text{TOTAL ENERGY CONSUMPTION} = \text{TOTAL FUEL INPUT} + \text{TOTAL ELECTRIC ENERGY} = 1.4012 + .9991 = 2.40\ \frac{\text{GBtu}}{\text{Year}}$$

$$\text{ENERGY BUDGET} = \frac{\text{TOTAL ENERGY CONS}}{\text{GROSS BUILDING AREA}} = \frac{2.40 \times 10^9}{9000} = 266{,}666 \text{ Btu/sq ft-year}$$

Figure 52. Central plant energy utilization summary and equipment use statistics.

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0 16 MAY 79 06.54.13

EQUIPMENT USE STATISTICS

EQUIPMENT	AVG OPER RATIO	MAX LOAD (KBTUH)	MON	DAY	HR	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS	SIZE (KBTUH)	OPER HRS
STEAM BOILER	.230	298.9	1	13	6	800.0	4344								
HERMETIC COMPRESSION CHILLER	.252	428.2	10	10	14	600.0	8760								

UTILITY, ENERGY	1YR UNADJ COST (K$)	1-YEAR USAGE (GBTU)	PEAK USAGE (KBTUH)	COST ESCALATION FACTOR
ELECT	12.5	.999	242.5	0.
BOILER	2.1	1.401	476.5	0.
UTILITY, ENERGY TOTAL	14.6			

Figure 52. (cont'd)

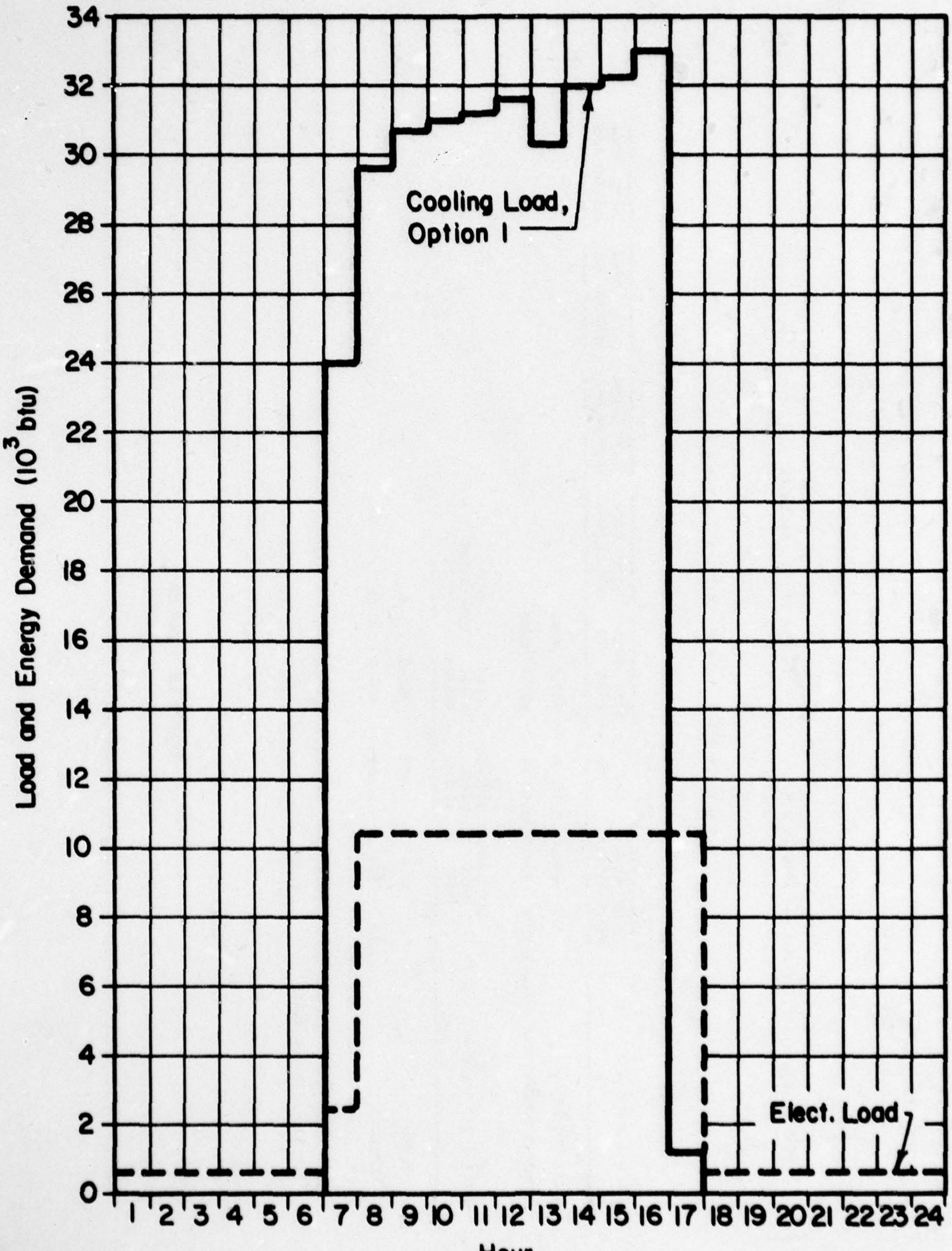

Figure 53. Summer design day, Option 1.

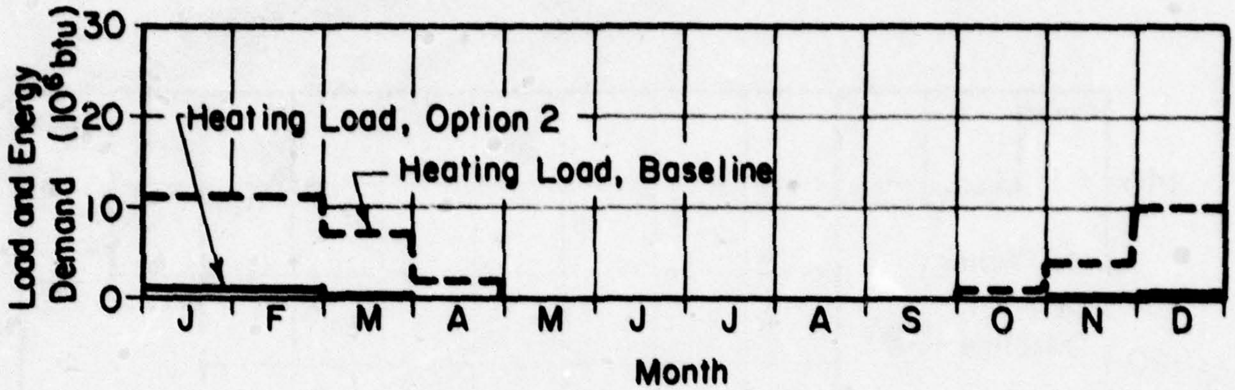

Figure 54. Heating loads, baseline vs Option 1.

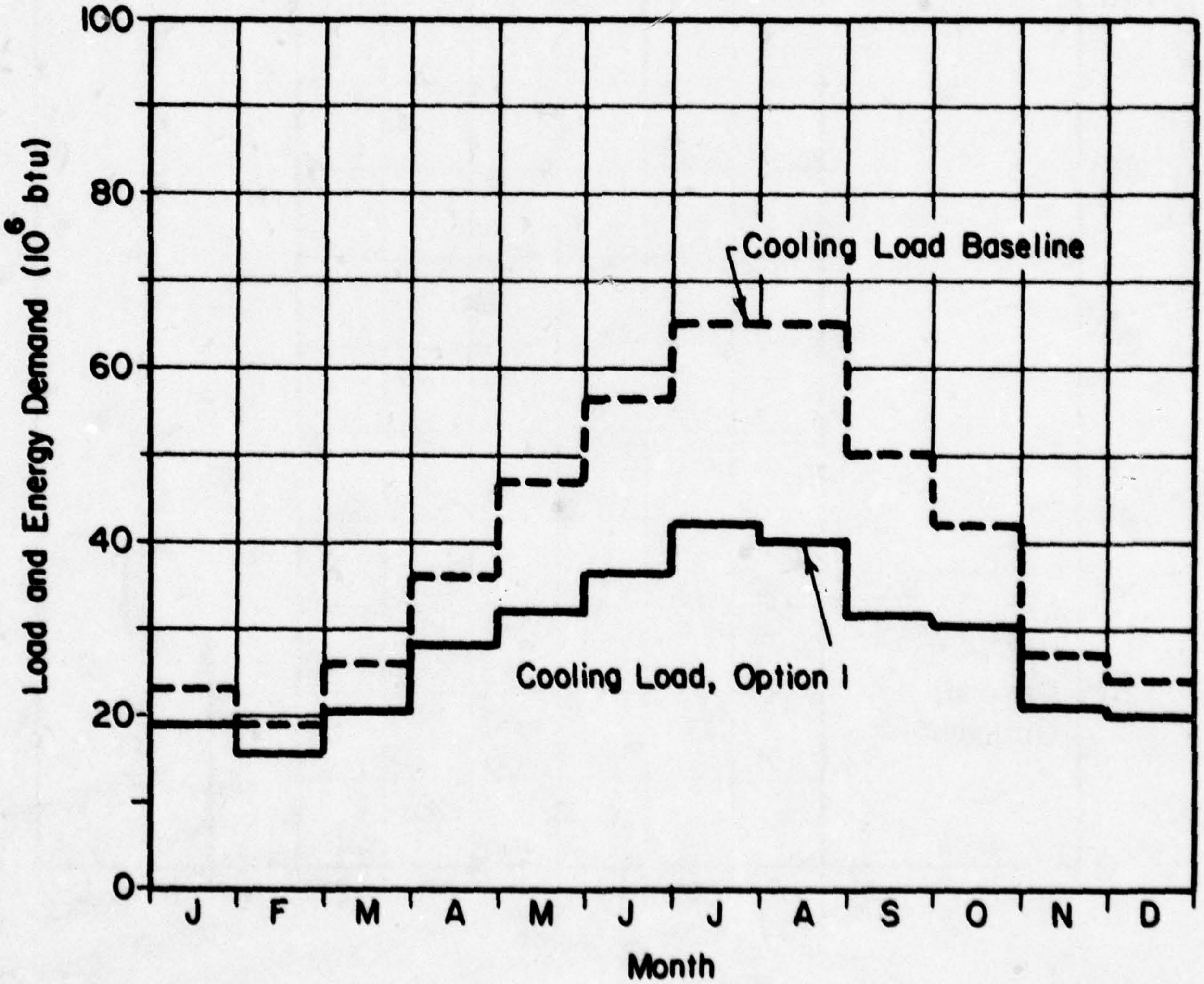

Figure 55. Cooling loads, baseline vs Option 1.

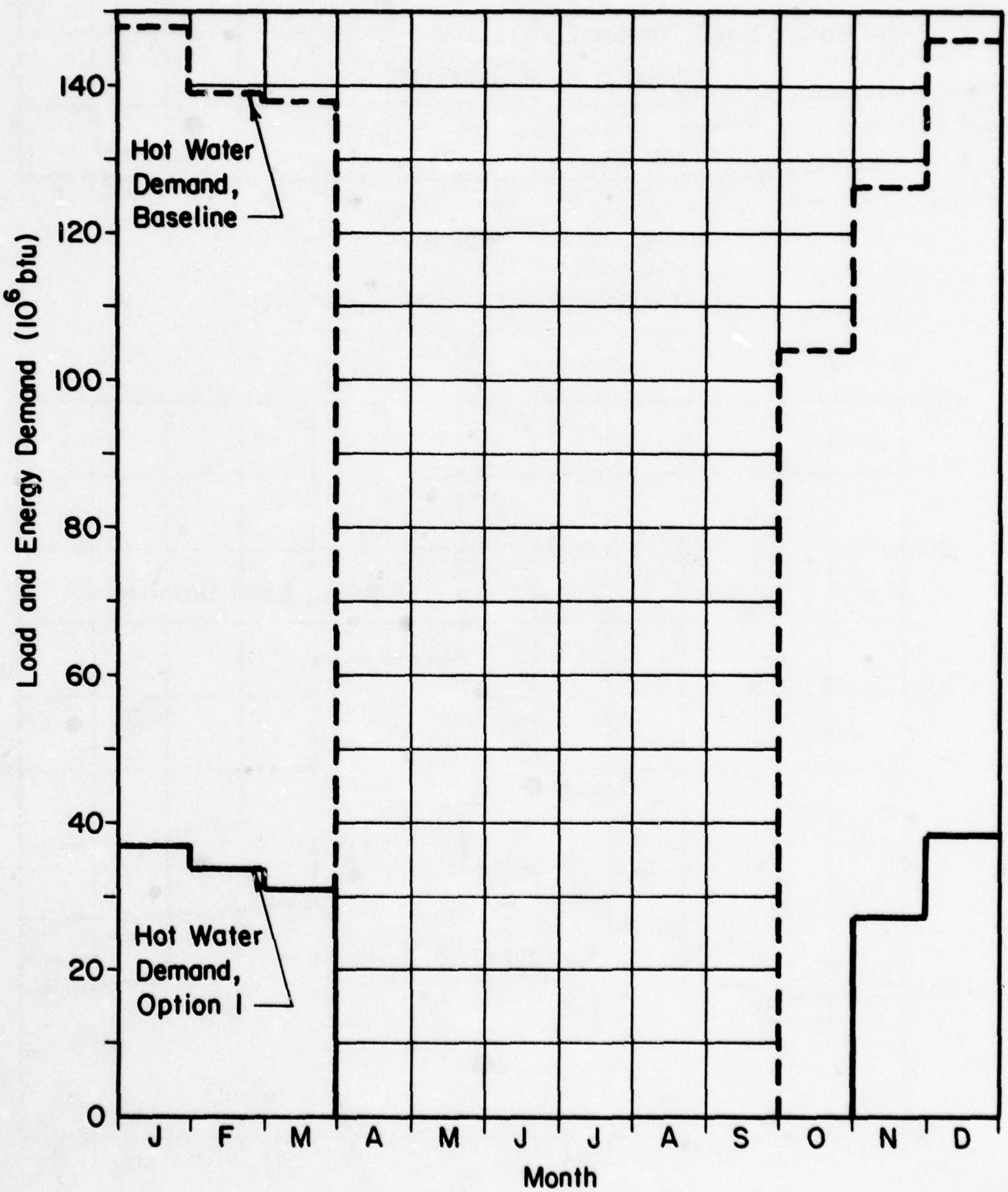

Figure 56. Hot water demand, baseline vs Option 1.

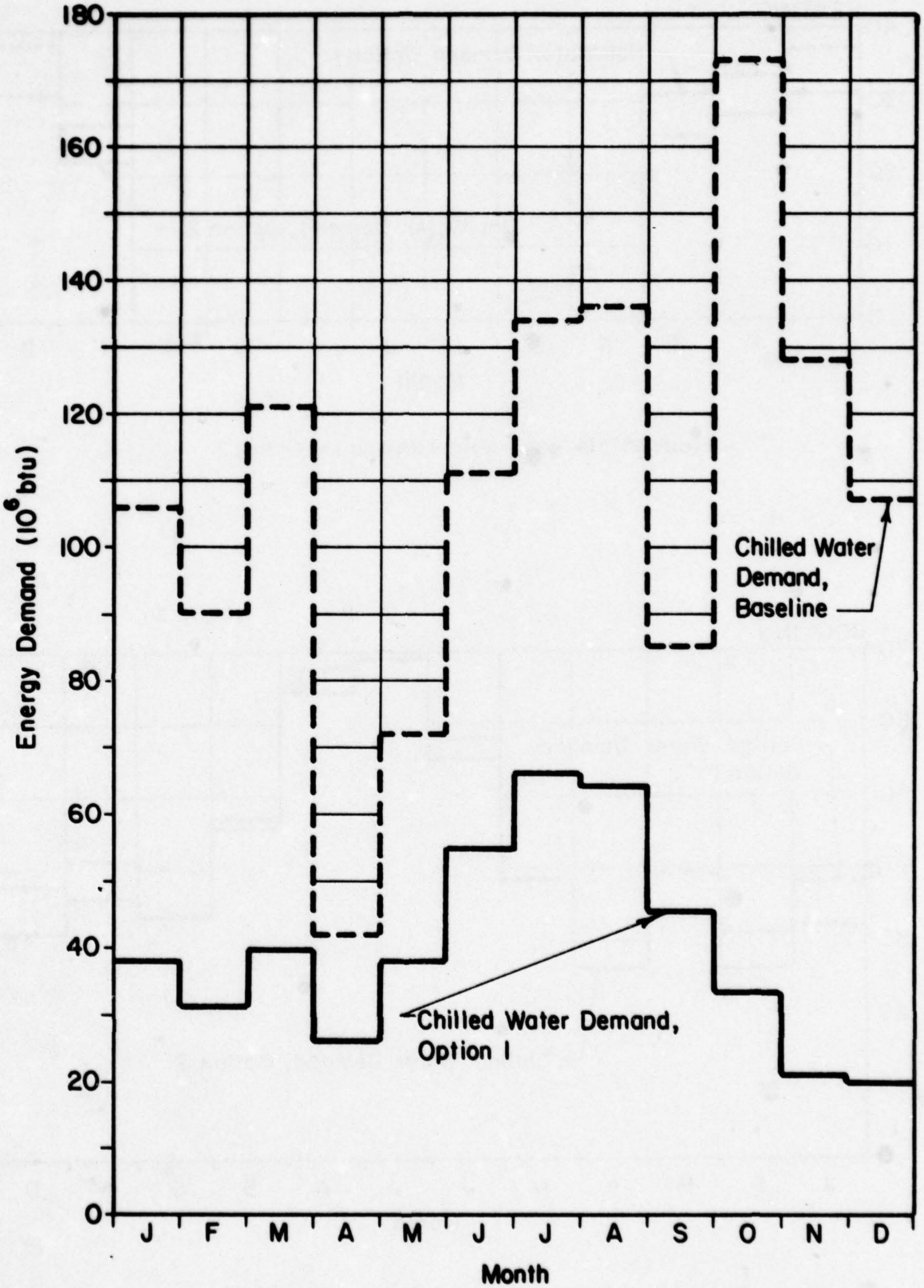

Figure 57. Chilled water demand, baseline vs Option 1.

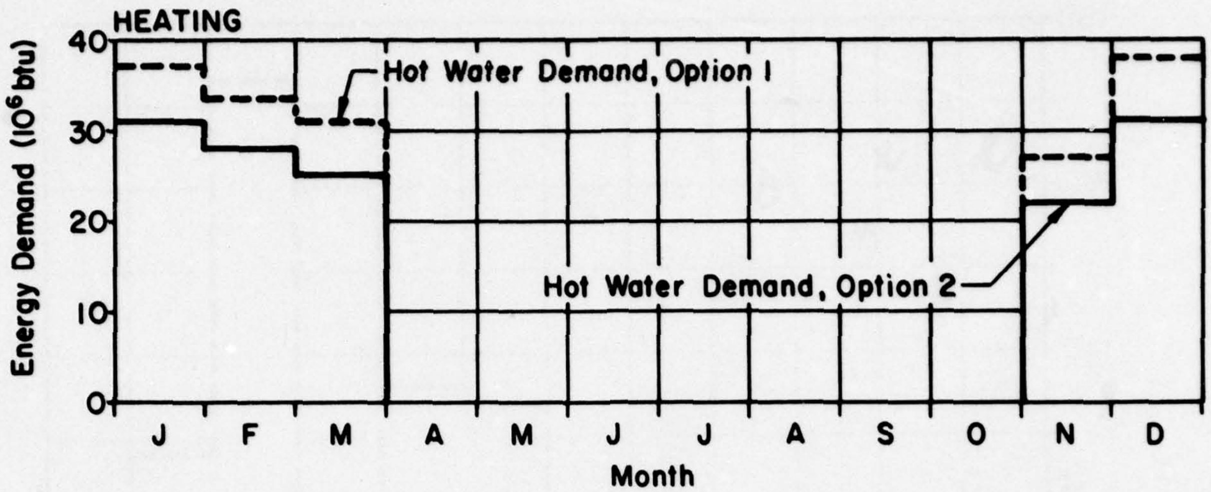

Figure 58. Hot water demand, Option 1 vs Option 2.

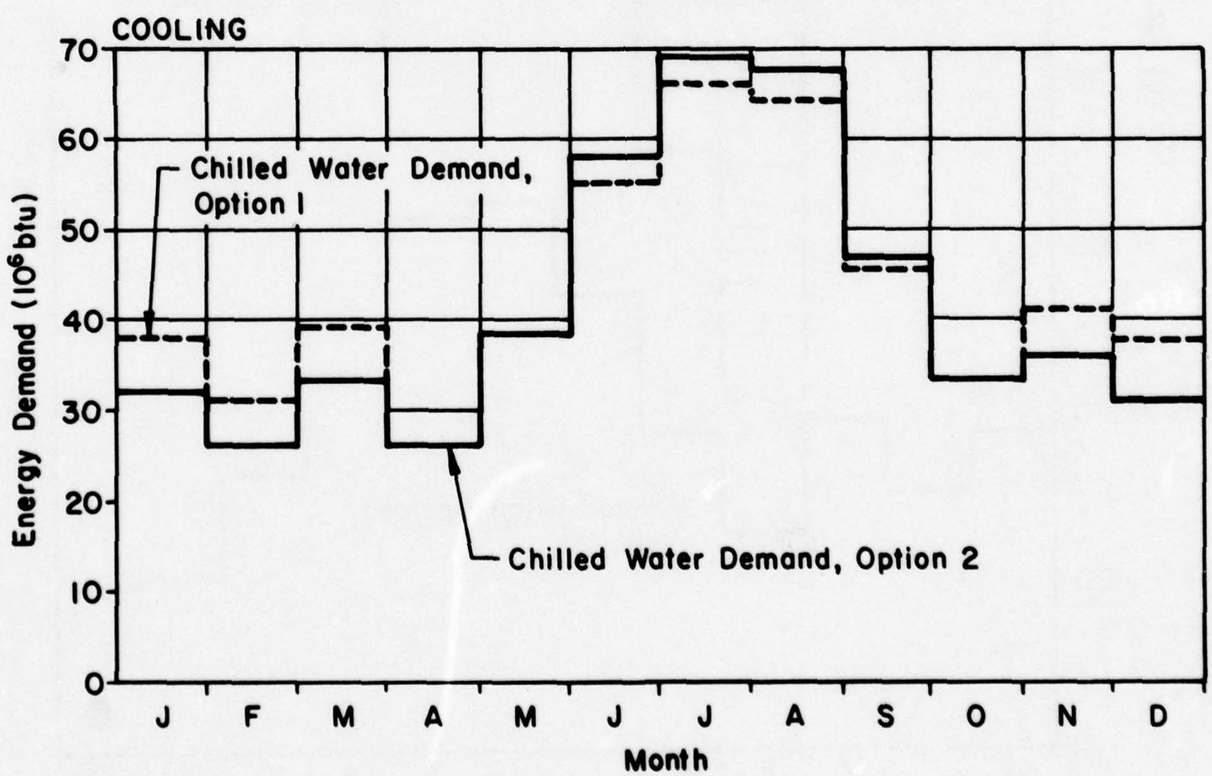

Figure 59. Chilled water demand, Option 1 vs Option 2.

Option 3 considered the conversion of the multizone fan system to a variable air volume fan system with terminal reheat. Several of the previous results have indicated the advantages of this system. First, the small heating loads of Options 1 and 2 indicate that small amounts of reheat will suffice to warm exterior zones when a heating load exists. Second, because of the high demand for cooling in winter, implementing an economy cycle appears to be desirable. However, with multizone systems, economy cycles often create increased heating demands, because the cool air introduced from outdoors passes over both the heating and cooling coils. On the other hand, a VAV system, which has only one deck, does not have this deficiency. Third, the VAV system allows for implementing a deadband room temperature control strategy.

Figure 60 shows the effect of implementing a deadband control strategy on the zone cooling loads (the heating loads have not been plotted, since they are virtually zero). The figure also shows the cooling load previously obtained from implementing night and weekend shutoff. Allowing the room temperature to float has reduced the cooling load. Figure 61 shows the chilled water demand of Option 3 (the VAV system) compared to the chilled water demand for Option 2 (the multizone system with night and weekend setback and hot and cold deck reset). Notice that the economy cycle has further reduced the chilled water demand during intermediate and winter seasons, and that the chilled water demand is somewhat less than the chilled water demands of the "best" multizone system (Option 2). An economic analysis is required to determine whether the improvement in performance of Option 3 over Option 2 justifies the expense of conversion.

A substantial reduction in the demand for chilled water and hot water can be achieved by using either Option 2 or Option 3. However, in examining the central plant report, it was found that both the peak and the average loads on the chiller and boiler are small compared to their capacity. Thus, only a part of the potential conservation has been achieved; smaller boilers and chillers should be considered to improve boiler efficiency and chiller COP (notice that considerable capital equipment cost could probably have been avoided if BLAST had been used to analyze this dental clinic before it was built).

Further review of the central plant energy use summary reveals that overall, the per-square-foot energy use in the building has been reduced considerably; based on recent standards, these reductions have probably met the building energy performance standard for this type of dental clinic. The building is estimated to consume 81 000 Btu/sq ft/year (27 733 kW/m^2/year) with the implementation of Option 3.

So far, there have been no changes to the building shell. Experience has shown that in retrofit applications, particularly for buildings of modern design, little economic benefit is achieved from modifying the building shell, particularly when compared to the economies that can be achieved by modifying the fan system and central plant. If energy use must be reduced further, re-evaluation of the building shell by simulating designs incorporating higher insulation level, more mass in the room, or reduced glass area would be in order. An economic analysis can be performed to determine whether to implement such modifications.

A review of the annual load calculation for each option revealed that extreme temperatures occasionally occur in various zones of the dental clinic due to the lack of cooling at night and on weekends and holidays. Whether or not these temperatures pose any hazard to the equipment or to the building itself should be determined before a final design is selected.

Table 16 and Figure 62 summarize the annual results and portray the differences in expected performance. It must be emphasized that the results of this case study are *not* general. While they

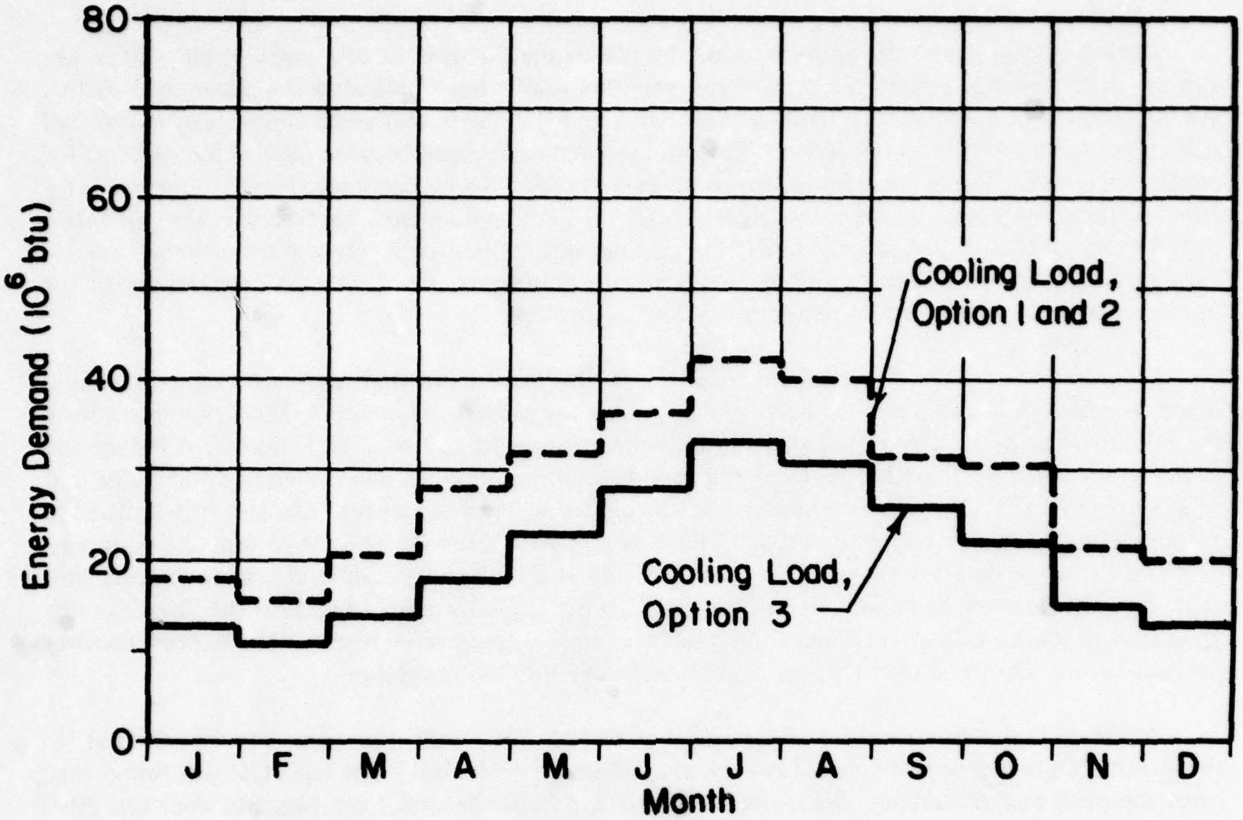

Figure 60. Effect of deadband room temperature control on cooling load.

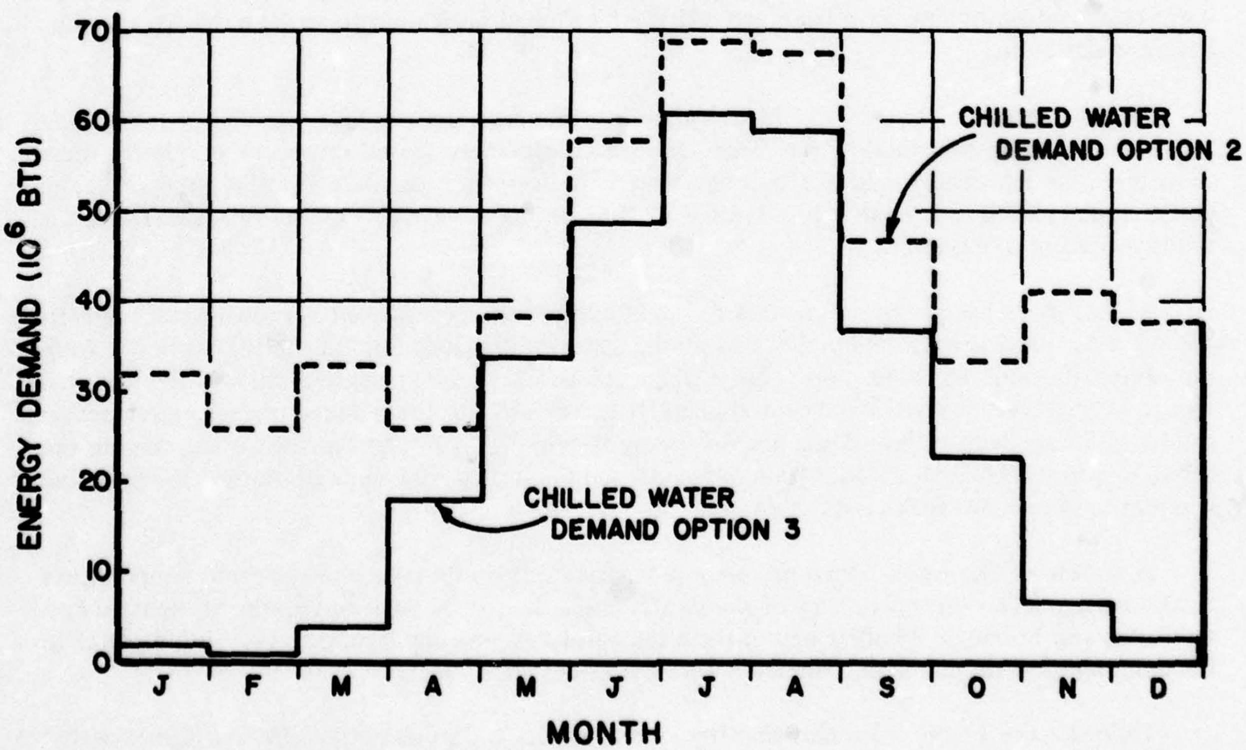

Figure 61. Chilled water demand, Option 2 vs Option 3.

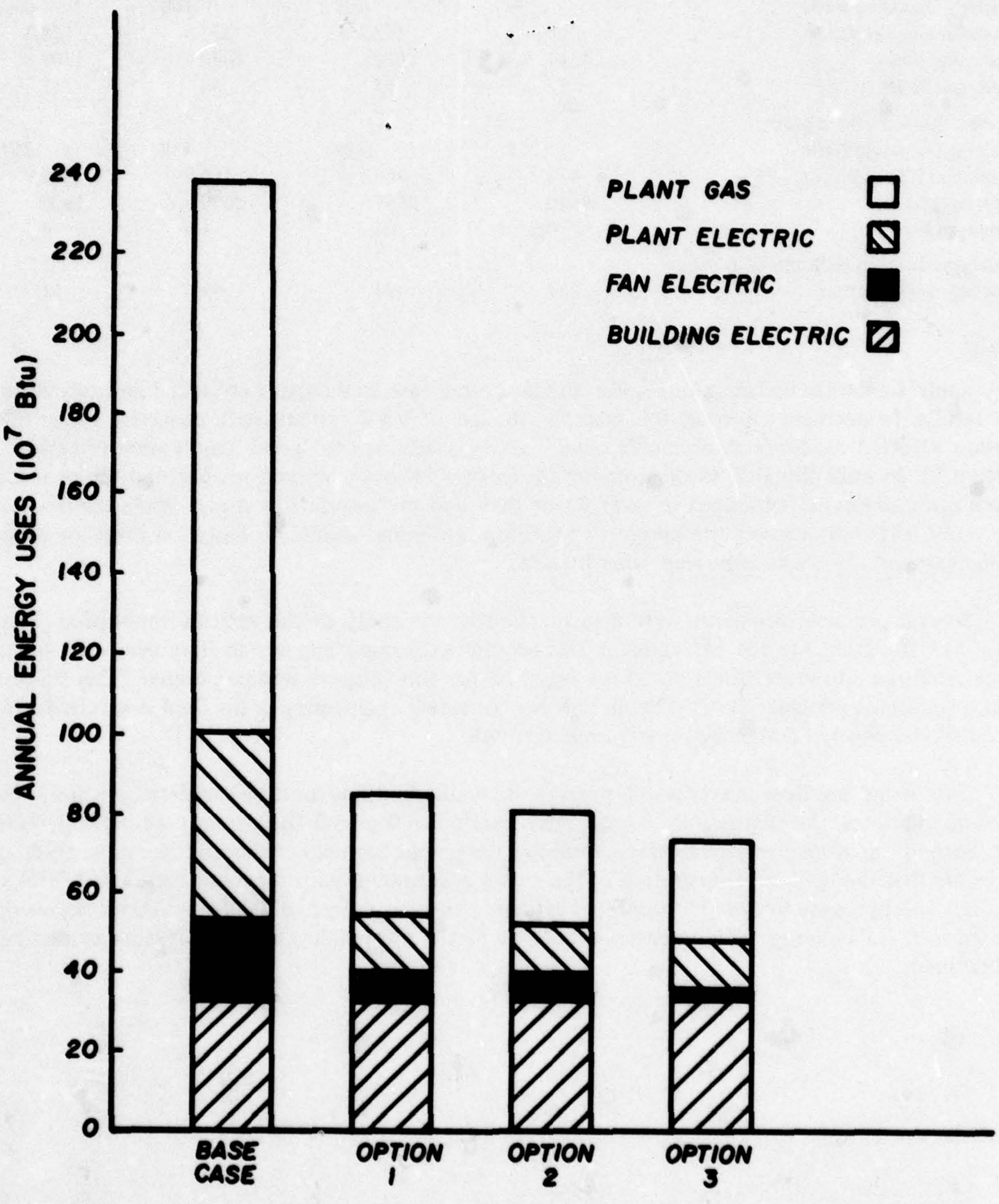

Figure 62. Annual energy use, baseline and Options 1, 2, and 3.

Table 16
Summary of Building Energy Analysis

	Baseline	Option 1	Option 2	Option 3
Boiler, 800 kBtu/hr capacity				
Average Operating Ratio	.230	.195	.160	.039
Maximum load (kBtu/hr)	298.9	282.2	237.3	128.3
Operating hours	4344	1070	1060	3707
Average efficiency (%)	57	55	54	47
Chiller, 600 kBtu/hr capacity				
Average Operating Ratio	.252	.329	.338	.264
Maximum load (kBtu/hr)	428.2	406.7	444.2	408.9
Operating hours	8640	2597	2000	1907
Average COP	4.2	4.6	4.6	4.1
Building boundary (kBtu/hr-sq ft-year) energy consumption	264	94	89	81

may apply to similar buildings in similar climates, other case studies have produced radically different results. In northern climates, for example, the use of VAV systems with economy cycles (like Option 3) often produces considerable energy savings compared to "good" multizone systems (like Option 2). In mild climates, the conversion to deadband room temperature control often produces much more dramatic reductions in room loads than was the case in this study. While the frequent use of BLAST will enhance the designer's intuition, no design should be based on intuition alone. Designs should always be evaluated using BLAST.

Several practical problems were also revealed in the study of this retrofit application. First, Option 1 (shutting the fan off at night and on the weekends) appears to have been part of the original design. However, the time clock installed for this purpose was inoperative. This suggests that no matter how carefully the simulation is performed, engineering in the field is required to be sure that the selected design is properly implemented.

The design problem is a two-step process. First, the building must be simulated precisely. For existing buildings, this will require considerable data collection and field examination of the building. Second, once an energy-conservative building design has been selected, great care must be taken to insure that the field implementation of the design corresponds with the design simulated. BLAST predicts energy consumption, but buildings actually consume energy. BLAST predictions set energy use goals for a building. These goals can only be met if the building is carefully constructed and maintained.

APPENDIX A: WEATHER TAPE CONVERSION

Introduction

The Weather Information File Encoder (WIFE) program starts with tapes from the National Climatic Center of National Oceanic and Atmospheric Agency (NOAA) to produce a file of surface and solar data in the proper form for use by the BLAST program. It will merge weather information from 1440 or Test Reference Year (TRY) format tapes with 280 format solar tapes; if no solar data are available, WIFE will create solar data using cloud cover data from the surface data tapes and approximative functions. WIFE can also process SOLMET or Typical Meteorological Year (TMY) format tapes; these tapes contain both surface and solar data. When the weather data are checked by WIFE, bad or missing data are replaced by the use of a trigonometric fit. Solar data are converted into beam and diffuse radiation components.

Input Data for WIFE

There are three input card images for WIFE.

The *first card* is 40 columns of alphanumeric data chosen by the user to identify the run.

The *second card* has both station and run data (separated by commas or blanks) as follows:

Table A1
Second Card Items and Format

Item	Format*	Comment
Latitude in degrees	Real	See Appendix E for data on Latitude,
Longitude in degrees	Real	Longitude, and Time Zone
Time Zone	Integer	
Station Number	Integer	1440, TRY, TMY, or SOLMET
280 Station Number	Integer	This is 0 if no solar 280 tape is used+
Start Year	Integer	Last 2 digits only**
Start Month	Integer	**
Start Day	Integer	**
Number of Days	Integer	If this is a 0, 1 year will be processed
Print Flag	Integer	If this is a 1, all data are printed, which is lengthy. Any other value gives monthly Summary reports.

* Real format is a number with a decimal point; an integer is a number with no decimal point.

\+ Solar 280 must not be used with TMY and SOLMET tapes.

**WIFE allows the user to choose run lengths of up to 1 year, which can begin on any day of the year. This allows a file to be encoded over a fiscal instead of calendar year or over a file of much smaller length than a year.

The *third card* specifies the type of format for the weather tape.

Table A2
Third Card Format

Anywhere on the Card	For Tape Type
Ø or "TRY"	TRY
1 or "SOLMET"	SOLMET
2 or "TMY"	TMY
anything else	144Ø

For example:

```
**TMY** FORT WORTH, TEXAS
32.75, 97.33, 6, Ø3927, Ø, 79, 1, 1, 365, Ø
"TMY"
```

Note that TMY tapes are composite year data. Users can pick any start year (1979 was input in the above example) when processing TMY tapes.

WIFE Output

WIFE gives the user a choice of two output reports. The first (print flag = 1) is a printout of all data, one day per page. The second (print flag ≠ 1) is a summary report (Figure A1). It has a cover page that lists the run identifier, a list of all inadequate days and a total of unreplaced days vs total days. There is one page per month giving daily summaries of high, low, and mean temperatures, heating and cooling degree days, and total solar radiation. At the bottom of each page is a monthly summary. The last page is a summary of the entire file.

All output is in centigrade temperature scales (W/m^2 for solar radiation). Both reports have cover page, monthly summaries, and last page summary.

Control Cards

The 144Ø, TRY, TMY, or SOLMET data tape must be made available to WIFE as local file TAPE1. The 280 series solar tape, if any, is made available to WIFE as local file TAPE3. WIFE creates a local file named TAPE2 that contains the processed data. This file is saved on tape or disk for later use. It will be supplied as local file WTHRFL when BLAST is run.

The control cards for WIFE may vary according to the computer site. A typical control card sequence is provided below.

```
--- Job Card ---
--- Account Card ---

Get TAPE1          -- input of 144Ø, TRY, SOLMET, or TMY
Get TAPE3          -- input of 280 solar
Get WIFE           -- binary version
```

WIFE:
Save TAPE2 -- output weather file.
7/8/9 - EOR Card
WIFE input
6/7/8/9 - EOI Card

Error Messages

The status of files and records is checked thr ughout WIFE. Inadequacies may terminate program execution. User errors can be classified into three categories:

1. A STOP "INPUT CARD ERROR" tells the user that he/she has not entered enough data. Usually this means that fewer than the three required data cards have been used.

2. A STOP "31 CONSECUTIVE BAD DAYS" tells the user that a block of data of approximately 1 month is missing from the weather data tape during the chosen run span. It is suggested that a different run span (e.g., a different year with same dates) be chosen.

3. A STOP "EOF ENCOUNTERED ON WEATHER TAPE" alerts the user that the data cannot be found on the requested data tape. Input data should be rechecked to see that it correlates with the tape data. If the wrong tape has been attached, or if the wrong station or year has been specified, an OPERATOR DROP may also occur. This means that one of the two input tapes has run off its reel. This can be a very expensive error.

Ordering Weather Tapes

Weather tapes can be ordered from NOAA, National Climatic Center, Federal Building, Asheville, NC 28801, (704) 258-2850. This agency has recently developed three tapes containing data for 1 year for 60 stations (cities) around the United States. These data are for TRY, according to ASHRAE-developed procedures. SOLMET tapes are historical data (about 20 years) for 26 U.S. stations and have both climate and solar information. TMY tapes are comprised of selected months from the SOLMET tapes; the selection is based on half solar, one-sixth dry bulb temperature, one-sixth dew-point, and one-sixth wind velocity. TMY tapes, therefore, are particularly good for applications with passive or active solar designs, or for buildings with large glass expanses.

If BLAST will be used at a site where it is already running, chances are good that these data are already available. If these data are not satisfactory or not available, appropriate data can be obtained from NOAA. Department of Defense users can receive the same data tapes from the Environmental Technical Applications Center (ETAC), Air Weather Service, USAF, Scott AFB, IL. Requests should be coordinated through a BLAST consultant.

TMY FORT WORTH, TEXAS

** NO SOLAR TAPE REQUESTED FOR THIS RUN **

STATION 03927 AT LOCATION, LAT= 32.75 LONG= 97.33 TIME ZONE= 6
STARTING DATE 1/ 1/1979 FOR 365 DAYS

INPUT TAPE ASSUMED TO BE TMY FORMAT

STARTING POSITION OF TMY TAPE, STATION 03927 YEAR 1979 MONTH 1 DAY 1

HAVE POSITIONED TMY TAPE TO STATION 03927 YEAR 1979 MONTH 1 DAY 1

THERE ARE 365 GOOD DAYS ON THIS 365 DAY TAPE.

Summary of Input and WIFE actions

DAILY STATISTICS FOR STTN = 3927, YEAR = 1979, MONTH = 1 PAGE 0

DAY OF MONTH	DAY OF YEAR	TEMPERATURES LOW	HIGH	MEAN	DEGREE DAYS HEATING	COOLING	TOTAL RADIATION
1	1	8.30	11.70	10.00	8.33	0.	1044.
2	2	3.30	13.30	8.30	10.03	0.	5812.
3	3	.60	15.00	7.80	10.53	0.	620.
4	4	-6.10	0.	-3.05	21.38	0.	865.
5	5	-8.90	2.20	-3.35	21.68	0.	7517.
6	6	-3.30	8.30	2.50	15.83	0.	6541.
7	7	-1.70	13.90	6.10	12.23	0.	7677.
8	8	4.30	15.60	9.95	8.38	0.	281.
9	9	6.10	17.20	11.65	6.68	0.	2607.
10	10	2.80	14.40	8.60	9.73	0.	1450.
11	11	1.70	16.10	8.90	9.43	0.	7877.
12	12	5.00	25.00	15.00	3.33	0.	7569.
13	13	2.20	13.00	7.60	10.73	0.	6651.
14	14	-3.30	7.80	2.25	16.08	0.	5999.
15	15	-8.30	2.20	-3.05	21.38	0.	6142.
16	16	-5.60	7.20	.80	17.53	0.	7738.
17	17	2.20	13.90	8.05	10.28	0.	1502.
18	18	12.80	23.90	18.35	0.	.02	3624.
19	19	11.10	22.20	16.65	1.68	0.	5501.
20	20	11.10	27.20	19.15	0.	.82	6512.
21	21	3.90	10.70	7.30	11.03	0.	870.
22	22	3.90	15.00	9.45	8.88	0.	4085.
23	23	3.30	23.90	13.60	4.73	0.	7256.
24	24	4.40	24.40	14.40	3.93	0.	5443.
25	25	2.20	15.00	8.60	9.73	0.	6715.
26	26	3.90	8.90	6.40	11.93	0.	744.
27	27	0.	8.30	4.15	14.18	0.	485.
28	28	-3.90	2.80	-.55	18.88	0.	2298.
29	29	-1.10	2.40	.65	17.68	0.	1256.
30	30	-1.70	9.40	3.85	14.48	0.	5497.
31	31	-2.80	9.40	3.30	15.03	0.	2724.

SUMMARY OF MONTH

AVERAGE MEAN TEMPERATURE = 7.20
TOTAL HEATING DEGREE DAYS = 345.72
TOTAL COOLING DEGREE DAYS = .84
AVERAGE TOTAL RADIATION = 4223.

Typical Monthly Weather Data Report

SUMMARY OF TAPE PAGE 13

AVERAGE MEAN TEMPERATURE = 18.41
TOTAL HEATING DEGREE DAYS = 1325.61
TOTAL COOLING DEGREE DAYS = 1353.71
AVERAGE TOTAL RADIATION = 6422.

Brief Annual Weather Data Summary

Figure A1. Sample WIFE output.

APPENDIX B: ACCESS CONTROL

The BLAST program is installed on Control Data Corporation (CDC) 6600, CYBER, or 7600 equipment. The following are sample job card sequences for running BLAST.

BLAST Files

The file names associated with the BLAST program are:

WTHRFL Weather file in BLAST-compatible form from which the BLAST program gets its weather data. This file should be "attached" for *all* BLAST runs except runs where DESIGN DAYS simulations only are desired.

OLDLIB File containing the defined materials, walls, roofs, floors, schedules, etc., making up the BLAST library.

NEWLIB File which contains the old library plus any changes made during a BLAST run. It should be saved whenever permanent entries, deletions, or changes are made to the program library which the user wishes to retain for use in future runs.

BLDFL Random access file created by the load-determining subprogram containing hourly zone loads and other data. It is required as an input file by the air distribution system simulation program and by the load-determining program itself whenever the ADD ZONES or REPLACE ZONES run control parameters are specified.

AHLDFL Random access file created by the air distribution system simulation subprogram containing hourly electrical power and heating and cooling coil energy demand and other data; it is required as an input file by the central energy plant simulation subprogram and by the air distribution system simulation program itself any time the ADD AIR SYSTEM or REPLACE AIR SYSTEMS run control parameters are specified.

BLAST Execution

Since the exact control cards used for attaching, cataloging, or saving programs and files differ with various computer sites, the following are typical examples without specific formats.

To run a complete BLAST job without saving any results:

{your job cards, charge cards, etc.}
Attach BLAST–gets executable code (compiled code) stored in the computer
Attach NEWLIB–gets the BLAST library
Attach WTHRFL–gets weather data file if needed
BLAST.
End of record card
[INPUT DATA]
End of information card

To save the BLDFL and/or AHLDFL files for later use or to save an updated program library, different procedures are used at different sites. The following example saves everything:

{Job Cards}
Attach BLAST–gets BLAST
Attach OLDLIB or NEWLIB–gets the BLAST library
Attach WTHRFL–gets weather data file
Request room (if necessary) to save BLDFL, ADHDFL, NEWLIB
BLAST.
Save NEWLIB–save new library
Save BLDFL–save building hourly loads file
Save AHLDFL–save hourly air-handling system simulation results
End of record card
[INPUT DATA]
End of information card

The next time BLAST is run, OLDLIB or NEWLIB should be attached using the most recent library stored. The BLDFL or AHLDFL files can be used in later BLAST runs by retrieving them from storage.

Users may attach their copy of the BLAST library as either OLDLIB or NEWLIB. In either case, if permanent changes are made, NEWLIB can be saved after running BLAST. If the library is attached as OLDLIB, BLAST will internally reorganize the library entries before adding any changes input by the user and before extracting the necessary data for the simulation. This reorganization (into a balanced "tree") is done to expedite the search for and extraction of data. Library reorganization requires some additional computer time; it is only necessary if *major* changes are made. And since the library is reorganized *before* user entries are inserted, the user library should be attached as OLDLIB *following* the run where major changes are made. The NEWLIB created in the second run should be used thereafter. The BLAST or user library should always be attached as NEWLIB except in the rare case when a user library (or basic library) is being built (or rebuilt).

For actual file retrieval at a particular site, contact the BLAST consultant for that site.

APPENDIX C: ABSORPTIVITY OF MATERIALS TO SOLAR RADIATION

Reprinted by permission from Thermal Radiation Properties Survey (Honeywell Research Center, Minneapolis, Minnesota, 1966), pp 245-248.

BUILDING MATERIALS, SOLAR ABSORPTIVITY

Material	Solar Absorptivity
BRICKS	
Clay, cream, glazed	0.36
Clay, Felton, dark portion	0.63
Clay, Felton, light portion	0.40
Lime clay, French	0.46
Gault, cream	0.36
Light buff	0.516
Light buff but darker than above	0.60
Mottled purple	0.77
Red	0.699
Red, common and tiles	0.68
Red, darker, glazed	0.766
Red, wire-cut	0.52
Stafford blue	0.89
Stock, light fawn	0.57
White glazed	0.26
White glazed (2 specimens)	0.25–0.27
TILES	
Clay, purple (dark)	0.82
Clay, dark purple, machine-made	0.81
Red	0.67
Red, hand-made	0.60
Red, light, Dutch	0.43
Red, light, machine-made	0.66
Red, light, machine-made	0.62
Concrete, uncolored	0.65
Concrete, black	0.91
Concrete, dark	0.91
Concrete, brown	0.85
Concrete, brown, very rough	0.88
ASPHALT	
New, 3 specimens	0.91
New, 3 specimens	0.91
New, another specimen	0.93
Pavement	0.852
Pavement, free from dust	0.928
Pavement, weathered, 3 specimens	0.82, 0.83, 0.89

BUILDING MATERIALS, SOLAR ABSORPTIVITY (Cont'd)

Material	Solar Absorptivity
ROOFING	
Bituminous felt, aluminized	0.40
Bituminous felt	0.88
Bituminous felt	0.89
Bitumin-covered, brown	0.87
Sheet, green	0.86
Sheet, black matte surface	0.97
Sheet, black matte surface	0.97
ASBESTOS CEMENT	
Aged	0.75
Aged 6 months	0.61
Aged 12 months	0.71
Aged 6 years, very dirty	0.83
Red	0.69
Red	0.74
Washed with soap and water	0.40
White	0.61
White (2 samples)	0.49–0.42
LIMESTONE	
Anston	0.60
Bath	0.53
Clipsham	0.46
Indiana	0.571
Ketton	0.42
Portland	0.36
Steetley	0.33
SAND-LIME	
Light-red	0.55
Red	0.68
White, fine sand	0.41
White, coarse sand	0.50
MARBLE	
White	0.44
Ground, unpolished	0.465
Cleavage	0.592
GRANITE	
Reddish	0.55
FELDSPAR	
$K_2O\ Al_2O_3\ 6SiO_2$	0.606
MORTAR SCREENED	0.73
SANDSTONE	
Grey, Bristol pennant	0.76
Polmaise, light fawn	0.54
Stancliffe, light grey	0.62
Woolton, red	0.73
WHITEWASH	
On galvanized iron	0.22
On galvanized iron	0.22
On galvanized iron	0.26
On galvanized iron, a very thick layer	0.20

BUILDING MATERIALS, SOLAR ABSORPTIVITY (Cont'd)

Material	Solar Absorptivity
OTHER MATERIALS	
Thickly tinned surface	0.05
Wood, smoothly planed	0.78
Basalt	0.72
Red sandstone	0.60
Marble (white)	0.58
Granite	0.45
Dolomite lime	0.41
Clay shale	0.69
Paris plaster	0.78
White plastered wall	0.92
Gravel	0.29
Sand	0.76
Glass	0.93
Sawdust	0.75
Clay	0.39
Red brick wall	0.93

PARACHUTE CLOTH, SOLAR ABSORPTIVITY, REFLECTIVITY, AND TRANSMISSIVITY

Material	Absorptivity	Reflectivity	Transmissivity
Dacron, 100 lb	0.05	0.35	0.60
Dacron, 300 lb	0.11	0.54	0.35
Dacron, 600 lb	0.12	0.61	0.27
Dacron, 800 lb	0.19	0.62	0.19
Nylon rip-stop (orange) 1.1 oz per sq yd, MIL-C-7020B Type I	0.13	0.23	0.64
Nylon rip-stop 1.1 oz per sq yd (white) MIL-C-7020	0.08	0.27	0.65
Nylon rip-stop 1.6 oz per sq yd (white) MIL-C-7020B Type III	0.06	0.22	0.72
Nylon cloth 2.25 oz per sq yd, MIL-C-7350B Type I	0.05	0.36	0.59
Nylon cloth 4.30 oz per sq yd, MIL-C-8021 Type I	0.08	0.44	0.48
Nylon cloth 7.0 oz per sq yd, MIL-C-8021 Type II	0.13	0.46	0.41
Nylon cloth 14.0 oz per sq yd, MIL-C-8021 Type III	0.11	0.62	0.27

CLOTH, SOLAR REFLECTIVITY

Material	Solar Reflectivity
QM1, cotton sheeting bleached, 4 oz per yd	0.62–0.66
QM2, cotton sateen prepared for dyeing, 9 oz per yd	0.68–0.72
QM4, cotton sateen undyed, 9 oz per yd	0.69–0.72
QM6, cotton sateen, medium gray, 9 oz per yd	0.53
QM7, cotton sateen dark gray, 9 oz per yd	0.24
50 percent wood, 50 percent cotton knit, undyed, 10.5 oz per yd	0.62
Cotton knit, undyed, 3 oz per yd	0.60

APPENDIX D: LOCATION DATA

Figure D1 indicates time zone boundaries in North America and the zone numbers. The Table D1 shows latitude and longitude for 50 major U.S. cities, with each state represented.

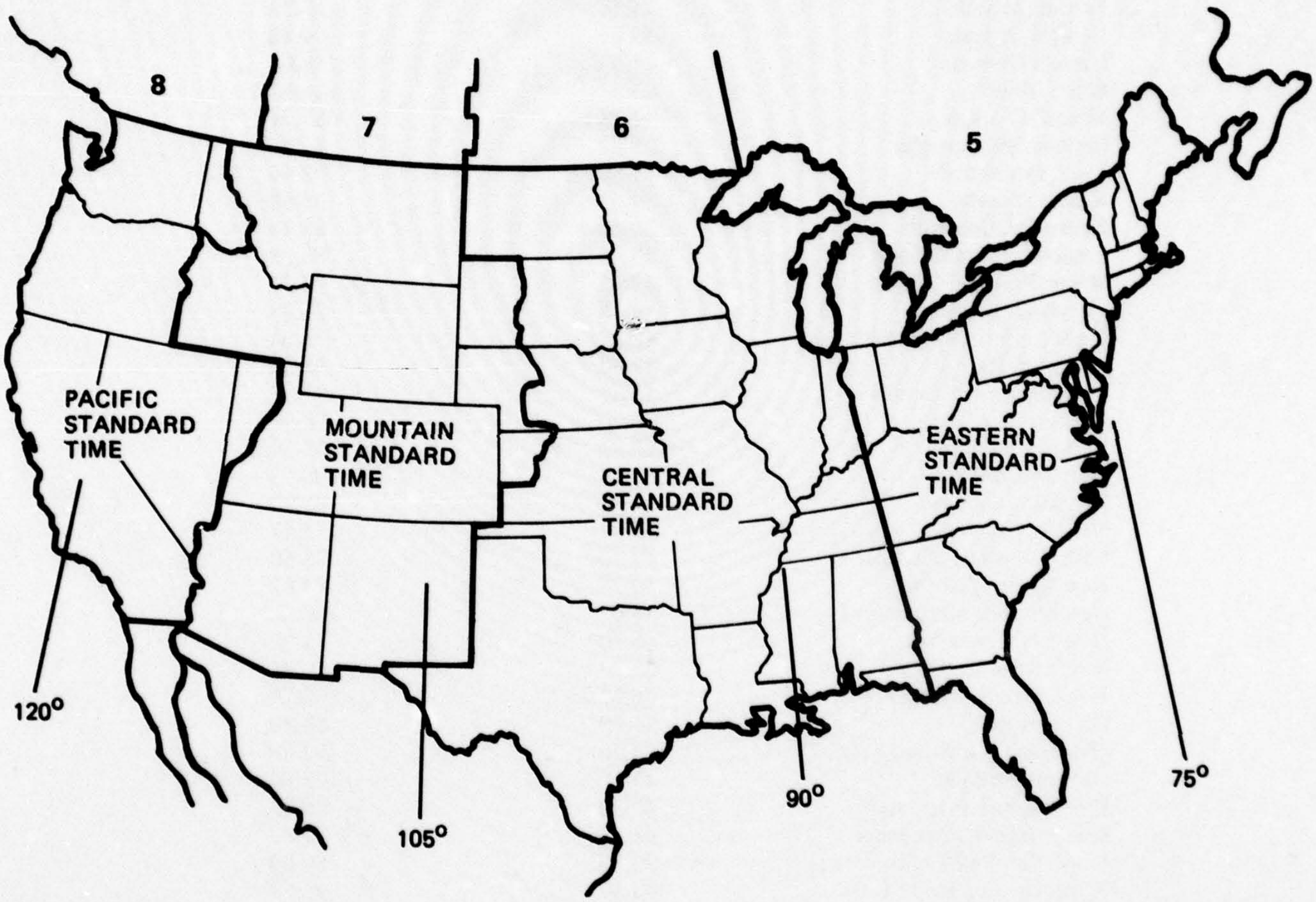

Figure D1. Time zone numbers in the United States.

Table D1
Latitude and Longitude of Some Major U.S. Cities

State, City	Latitude (Deg N)	Longitude (Deg W)
Alabama, Mobile	30.70	88.03
Alaska, Fairbanks	64.82	147.87
Arizona, Phoenix	34.45	112.07
Arkansas, Little Rock	34.73	92.23
California, San Francisco	37.62	122.55
Colorado, Denver	39.77	104.88
Connecticut, Hartford	41.73	72.65
Deleware, Wilmington	39.67	75.60
Florida, Miami	25.78	80.28
Georgia, Atlanta	33.65	84.42
Hawaii, Helemano	21.53	158.03
Idaho, Boise	43.57	116.22
Illinois, Chicago	41.78	87.75
Indiana, Indianapolis	39.73	86.27
Iowa, Des Moines	41.53	93.65
Kansas, Topeka	39.05	95.68
Kentucky, Louisville	38.18	85.73
Louisiana, New Orleans	29.98	90.25
Maine, Portland	43.65	70.32
Maryland, Baltimore	39.18	76.77
Massachusetts, Cambridge	42.38	71.08
Michigan, Detroit	42.40	83.00
Minnesota, Minneapolis	44.88	93.25
Mississippi, Biloxi	30.40	88.90
Missouri, Columbia	38.97	92.37
Montana, Billings	45.80	108.53
Nebraska, Omaha	41.30	95.90
Nevada, Las Vegas	36.07	115.17
New Hampshire, Concord	43.20	71.50
New Jersey, Trenton	40.27	74.82
New Mexico, Albuquerque	35.05	106.62
New York, New York	40.70	74.02
North Carolina, Charlotte	35.23	80.93
North Dakota, Bismarck	46.77	100.75
Ohio, Dayton	39.90	84.20
Oklahoma, Oklahoma City	35.40	97.60
Oregon, Portland	45.60	122.60
Pennsylvania, Pittsburgh	40.50	80.22
Rhode Island, Providence	41.73	71.43
South Carolina, Charleston	32.50	80.00
South Dakota, Sioux Falls	43.57	96.73
Tennessee, Memphis	35.05	89.98
Texas, Fort Worth	32.75	97.33
Utah, Salt Lake City	40.78	111.97
Vermont, Burlington	44.47	73.15
Virginia, Norfolk	36.88	76.20
Washington, Seattle	47.45	122.30
West Virginia, Wheeling	40.18	80.65
Wisconsin, Madison	43.13	89.33
Wyoming, Cheyenne	41.15	104.82

APPENDIX E: EARTH TEMPERATURE TABLES FOR UNDERGROUND HEAT DISTRIBUTION SYSTEM DESIGN

The tables in this appendix are from T. Kusuda, *NBSD Computer Program for Heating and Cooling Loads in Buildings,* NBSIR 74-574 (National Bureau of Standards, November 1974). They were developed by applying monthly average temperatures prepared by the U.S. Weather Bureau for many localities in the United States to a technique described in the *Earth Temperature and Thermal Diffusivity at Selected Stations in the United States* by T. Kusuda and P. R. Achenbach (ASHRAE, 1965). These temperature data are, however, for the undisturbed earth. The earth temperature immediately under the building may be estimated by taking an arithmetic average of the building temperature and the design earth temperature found in the appropriate table.

For example, the ground temperature for a building in Washington, D. C. should be estimated as follows:

Select the soil condition (e.g., average soil), season (e.g., summer), and the nearest site (e.g., Upper Marlboro, MD) from the Tables E1 through E3. These give a summer average earth temperature of 66°F (18°C).

Select a building temperature (e.g., 72°F [22°C]) and use it to compute the required summer ground temperature for BLAST. In this case: $0.5(66 + 72) = 69°F$ (18°C).

Compute temperature for other seasons similarly and interpolate to determine all twelve monthly temperatures.

Table E1
Dry Soil

AVERAGE EARTH TEMPERATURE IN DEG. F., TG
THERMAL DIFFUSIVITY IN FT**2/HR ALPHA = .010

STATION STATE	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	60	61	71	70	65
DECATUR, ALABAMA	52	54	65	65	59
PALMER AAES, ALASKA	31	31	42	41	36
TEMPE, ARIZONA	62	64	73	74	68
TUCSON, ARIZONA	68	69	77	79	73
BRAWLEY, CALIFORNIA	70	73	83	84	77
DAVIS, CALIFORNIA	61	61	72	72	67
FT. COLLINS, COLO..	44	45	58	56	51
STORRS, CONN.	46	45	58	58	52
GAINESVILLE, FLA.	65	70	77	77	73
ATHENS, GEORGIA	59	61	72	72	66
MOSCOW, IDAHO	43	42	52	52	47
LEMONT, ILLINOIS	46	45	59	59	52
URBANA, ILLINOIS	46	47	61	60	53
WEST LAFAYETTE, IND.	47	47	62	61	54
AMES, IOWA	44	45	62	60	52
BURLINGTON, IOWA	47	49	66	65	56
CASTANA, IOWA	42	42	61	59	51
COUNCIL BLUFFS, IOWA	47	47	62	62	55
SARATOGA, IOWA	41	40	59	57	49
SPENCER, IOWA	42	42	58	57	50
GARDEN CITY, KANSAS	48	51	66	66	58
MANHATTAN, KANSAS	48	50	64	64	56
MOUND VALLEY, KANSAS	52	54	68	68	60
LEXINGTON, KENTUCKY	51	52	65	64	58
UPPER MARLBORO, MD.	48	49	63	63	56
EAST LANSING, MICH.	45	43	57	57	50
FAIRMONT, MINNESOTA	42	43	58	57	50
FARIBAULT, MINNESOTA	40	40	55	53	47
ST. PAUL, MINNESOTA	42	40	57	56	49
WASECA, MINNESOTA	41	46	59	54	50
STATE UNIV., MISS.	60	62	73	73	67
FAUCETT, MISSOURI	47	47	61	61	54
KANSAS CITY, MO.	48	49	62	61	55
SIKESTON, MISSOURI	52	54	67	67	60
SPICKARD, MISSOURI	50	49	60	62	55
BOZEMAN, MONTANA	39	37	50	48	43
HUNTLEY, MONTANA	44	44	58	57	50
LINCOLN, NEBRASKA	45	45	60	60	53
NEW BRUNSWICK, N.J.	48	48	60	60	54
ITHACA, NEW YORK	44	43	54	54	49
COLUMBUS, OHIO	47	47	59	60	53
COSHOCTON, OHIO	46	46	58	58	52
WOOSTER, OHIO	46	46	58	58	52
BARNSDALL, OKLAHOMA	56	57	69	69	63
LAKE HEFNER, OKLA.	56	57	70	71	64
PAWHUSKA, OKLAHOMA	54	55	68	68	61
OTTAWA, ONTARIO	42	39	54	52	47
CORVALLIS, OREGON	50	51	61	60	55
HOOD RIVER, OREGON	46	48	57	57	52
MEDFORD, OREGON	51	52	61	61	56
PENDLETON, OREGON	46	49	61	60	54
STATE COLLEGE, PA.	46	45	59	58	52
KINGSTON, R.I.,	45	43	55	56	50
CALHOUN, S. CAROLINA	56	58	70	69	63
MADISON, S. DAKOTA	40	40	54	54	47
JACKSON, TENNESSEE	53	55	66	64	59
TEMPLE, TEXAS	64	65	77	77	71
SALT LAKE CITY, UTAH	44	45	56	55	50
BURLINGTON, VERMONT	42	40	54	53	48
PULLMAN, WASHINGTON	43	46	55	52	50
SEATTLE, WASHINGTON	48	50	56	56	53
AFTON, WYOMING	43	43	53	53	48

Table E2
Average Soil

AVERAGE EARTH TEMPERATURE IN DEG. F., TG
THERMAL DIFFUSIVITY IN FT2/HR ALPHA = .025**

STATION STATE	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	57	61	74	70	65
DECATUR, ALABAMA	49	53	69	66	59
PALMER AAES, ALASKA	29	30	45	41	36
TEMPE, ARIZONA	58	63	77	74	68
TUCSON, ARIZONA	65	69	80	80	73
BRAWLEY, CALIFORNIA	66	73	87	85	77
DAVIS, CALIFORNIA	57	60	76	73	67
FT. COLLINS, COLO..	40	44	62	57	51
STORRS, CONN.	43	44	62	59	52
GAINESVILLE, FLA.	61	71	79	78	73
ATHENS, GEORGIA	55	60	75	73	66
MOSCOW, IDAHO	40	42	55	53	47
LEMONT, ILLINOIS	42	44	64	60	52
URBANA, ILLINOIS	42	47	65	61	53
WEST LAFAYETTE, IND.	43	47	66	62	54
AMES, IOWA	39	44	67	61	52
BURLINGTON, IOWA	42	48	71	66	56
CASTANA, IOWA	36	41	66	61	51
COUNCIL BLUFFS, IOWA	42	47	67	63	55
SARATOGA, IOWA	37	39	64	58	49
SPENCER, IOWA	37	41	62	58	50
GARDEN CITY, KANSAS	42	51	71	67	58
MANHATTAN, KANSAS	44	49	68	65	56
MOUND VALLEY, KANSAS	47	54	72	69	60
LEXINGTON, KENTUCKY	47	51	69	65	58
UPPER MARLBORO, MD.	44	49	66	64	56
EAST LANSING, MICH.	41	41	61	58	50
FAIRMONT, MINNESOTA	38	43	63	57	50
FARIBAULT, MINNESOTA	36	38	59	54	47
ST. PAUL, MINNESOTA	38	38	62	57	49
WASECA, MINNESOTA	36	47	64	54	50
STATE UNIV., MISS.	56	62	76	74	67
FAUCETT, MISSOURI	43	45	65	61	54
KANSAS CITY, MO.	44	48	65	62	55
SIKESTON, MISSOURI	48	54	72	68	60
SPICKARD, MISSOURI	47	48	63	64	55
BOZEMAN, MONTANA	36	36	53	49	43
HUNTLEY, MONTANA	40	43	63	57	50
LINCOLN, NEBRASKA	40	44	65	61	53
NEW BRUNSWICK, N.J.	44	47	63	61	54
ITHACA, NEW YORK	41	41	58	54	49
COLUMBUS, OHIO	43	46	63	61	53
COSHOCTON, OHIO	42	45	61	59	52
WOOSTER, OHIO	42	45	62	59	52
BARNSDALL, OKLAHOMA	53	56	73	70	63
LAKE HEFNER, OKLA.	52	56	74	72	64
PAWHUSKA, OKLAHOMA	50	54	72	68	61
OTTAWA, ONTARIO	39	37	58	52	47
CORVALLIS, OREGON	47	50	64	60	55
HOOD RIVER, OREGON	43	48	59	57	52
MEDFORD, OREGON	48	52	64	61	56
PENDLETON, OREGON	41	49	65	61	54
STATE COLLEGE, PA.	42	44	63	59	52
KINGSTON, R.I.,	41	41	58	57	50
CALHOUN, S. CAROLINA	52	57	73	70	63
MADISON, S. DAKOTA	36	38	59	55	47
JACKSON, TENNESSEE	50	55	69	64	59
TEMPLE, TEXAS	61	65	81	77	71
SALT LAKE CITY, UTAH	40	45	60	56	50
BURLINGTON, VERMONT	39	38	59	54	48
PULLMAN, WASHINGTON	40	45	58	52	50
SEATTLE, WASHINGTON	46	50	59	56	53
AFTON, WYOMING	41	42	56	53	48

Table E3
Wet Soil

AVERAGE EARTH TEMPERATURE IN DEG. F., TG
THERMAL DIFFUSIVITY IN FT2/HR ALPHA = .050**

STATION STATE	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	54	61	76	70	65
DECATUR, ALABAMA	46	53	71	65	59
PALMER AAES, ALASKA	27	30	48	41	36
TEMPE, ARIZONA	56	64	79	74	68
TUCSON, ARIZONA	62	69	82	81	73
BRAWLEY, CALIFORNIA	63	73	90	84	77
DAVIS, CALIFORNIA	55	60	78	73	67
FT. COLLINS, COLO..	37	45	65	56	51
STORRS, CONN.	40	44	65	59	52
GAINESVILLE, FLA.	58	72	81	79	73
ATHENS, GEORGIA	52	61	78	73	66
MOSCOW, IDAHO	38	42	57	53	47
LEMONT, ILLINOIS	39	44	67	60	52
URBANA, ILLINOIS	39	47	68	60	53
WEST LAFAYETTE, IND.	40	47	69	62	54
AMES, IOWA	35	44	70	61	52
BURLINGTON, IOWA	38	48	74	66	56
CASTANA, IOWA	32	42	70	61	51
COUNCIL BLUFFS, IOWA	39	47	70	63	55
SARATOGA, IOWA	33	39	68	58	49
SPENCER, IOWA	33	42	66	58	50
GARDEN CITY, KANSAS	38	52	74	67	58
MANHATTAN, KANSAS	40	49	72	65	56
MOUND VALLEY, KANSAS	44	55	75	69	60
LEXINGTON, KENTUCKY	44	51	72	65	58
UPPER MARLBORO, MD.	41	49	69	64	56
EAST LANSING, MICH.	39	41	64	57	50
FAIRMONT, MINNESOTA	35	43	67	57	50
FARIBAULT, MINNESOTA	34	38	62	54	47
ST. PAUL, MINNESOTA	35	38	65	57	49
WASECA, MINNESOTA	31	49	67	53	50
STATE UNIV., MISS.	53	62	78	74	67
FAUCETT, MISSOURI	41	45	68	61	54
KANSAS CITY, MO.	41	48	68	61	55
SIKESTON, MISSOURI	45	54	75	68	60
SPICKARD, MISSOURI	44	48	65	64	55
BOZEMAN, MONTANA	34	35	57	48	43
HUNTLEY, MONTANA	37	43	66	57	50
LINCOLN, NEBRASKA	36	44	68	62	53
NEW BRUNSWICK, N.J.	41	47	66	62	54
ITHACA, NEW YORK	39	41	61	54	49
COLUMBUS, OHIO	40	47	65	61	53
COSHOCTON, OHIO	40	45	64	60	52
WOOSTER, OHIO	40	45	65	59	52
BARNSDALL, OKLAHOMA	50	56	75	70	63
LAKE HEFNER, OKLA.	49	57	77	73	64
PAWHUSKA, OKLAHOMA	48	54	75	68	61
OTTAWA, ONTARIO	37	37	61	51	47
CORVALLIS, OREGON	45	51	67	60	55
HOOD RIVER, OREGON	41	49	61	57	52
MEDFORD, OREGON	46	52	66	61	56
PENDLETON, OREGON	38	50	68	60	54
STATE COLLEGE, PA.	40	44	66	59	52
KINGSTON, R.I.,	39	41	61	57	50
CALHOUN, S. CAROLINA	49	58	76	69	63
MADISON, S. DAKOTA	33	38	62	55	47
JACKSON, TENNESSEE	48	55	72	64	59
TEMPLE, TEXAS	58	65	84	77	71
SALT LAKE CITY, UTAH	37	45	62	55	50
BURLINGTON, VERMONT	37	38	62	54	48
PULLMAN, WASHINGTON	37	45	60	50	50
SEATTLE, WASHINGTON	44	50	60	56	53
AFTON, WYOMING	39	42	59	53	48

APPENDIX F: FAN SYSTEM MODELS

Fan Coil Simulation

A separate model for fan coil cooling was developed because (1) fan coil units usually do not control the leaving air dry bulb temperature and (2) catalog data available for fan coil units differ from what are typically available for large cooling coils. (The simulation of heating coils is similar to other systems since only sensible heating is involved.) Within the simulation, there are coefficients for three curves relating the total cooling load to the sensible cooling load:

1. A four-row coil

2. A two-row coil

3. A four-row split coil with three rows used for cooling.

These three curves reflect coils typically used in fan coil applications and give the ratio of total to sensible cooling as a function of (1) entering air dewpoint temperature, (2) entering air dry bulb temperature, (3) entering water temperature, (4) air volume flow rate, and (5) water volume flow rate. They are based on manufacturer's catalog data. If a user wishes to override the defaults for fan coil cooling simulation, he/she must input a single design point for a particular fan coil cooling coil. From this design point, the program computes which of the three curves in BLAST most nearly intercepts the user-specified design point. The program uses that curve in the hourly simulation to determine (1) the total to sensible cooling load ratio on the coil and (2) the total cooling load. Design point data consist of (1) entering water temperature, (2) entering air dry bulb temperature, (3) entering air wet bulb temperature, (4) leaving water temperature, (5) leaving dry bulb temperature, (6) air volume flow rate, and (7) the barometric pressure. They are based on manufacturer's catalog data. The following example shows a typical COOLING COIL DESIGN PARAMETERS specification and the defaults (in English units; metric conversion factor °C = (F° − 32) X 5/9).

```
COOLING COIL DESIGN PARAMETERS:
     ENTERING WATER TEMPERATURE = 45;
     ENTERING AIR DRY BULB TEMPERATURE = 8Ø;
     ENTERING AIR WET BULB TEMPERATURE = 67;
     LEAVING WATER TEMPERATURE = 54.6;
     LEAVING AIR DRY BULB TEMPERATURE = 6Ø.4;
     WATER VOLUME FLOW RATE = 4.Ø;
     AIR VOLUME FLOW RATE = 6ØØ;
     BAROMETRIC PRESSURE = 4Ø6.8;
END COOLING COIL PARAMETERS;
```

Some OTHER SYSTEM PARAMETERS also affect the simulation of fan coil systems. The fan coil simulation allows outside air to be introduced *only* as a fixed percent of the supply air volume; this will happen no matter what the user specifies as the mixed-air control strategy. Relevant OTHER SYSTEM PARAMETERS are shown below with their default values in English units; metric units are in parentheses:

```
OTHER SYSTEM PARAMETERS:
     SUPPLY FAN PRESSURE = 2.5; (620 Pa)
     SUPPLY FAN EFFICIENCY = .7;
     COLD DECK CONTROL = FIXED SET POINT;
     COLD DECK TEMPERATURE = 55; (12.8°C)
     HOT DECK CONTROL = FIXED SET POINT;
     HOT DECK TEMPERATURE = 140; (60°C)
     HEATING COIL CAPACITY = 3412000; (1000000 kW)
     HEATING COIL ENERGY SUPPLY = HOT WATER;
     WEEKDAY MINIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - .15);
     WEEKEND MINIMUM OUTSIDE AIR SCHEDULE = (00 TO 24 - 00);
END OTHER SYSTEM PARAMETERS;
```

The default values for fan pressure and fan efficiency (which are used to determine the fan power for the fan coil unit) are probably too high and should be adjusted by the users. Fan coil unit fans are typically only about 40 to 50 percent efficient; the supply fan pressure may be as low as 0.5 in. of water (124 Pa). The cold and hot deck control and temperature sequences specified or defaulted are used by BLAST to program the water temperature, not the air temperature, going to the fan coil unit. Note that entering water temperature is one factor determining the sensible-to-total cooling ratio of the fan coil unit. The heating coil capacity specified in OTHER SYSTEM PARAMETERS is the design capacity of the fan coil unit for heating. Except for the input shown above, all OTHER SYSTEM PARAMETERS have no meaning for fan coil units.

Users must be careful with equipment schedules specified for fan coil units. As with other types of fan systems, if system operation is specified as CONTINUOUS, the fan in the fan coil unit runs continuously and the coils are cycled in response to the heating and cooling loads in the space. If the system operation is INTERMITTENT, the fan will run for the period when it is scheduled to be on. When it is scheduled to be off, but there is a load on the fan coil, the fan runs for the entire hour in which the load occurs. Notice that for a two-pipe fan coil system, the heating and cooling seasonal schedules must be adjusted by the user so that they do not overlap. The zone temperature control strategy corresponding to the daily and seasonal availability of heating and cooling should be specified when calculating the building loads.

In general, each fan coil unit represents a separate system. However, if there are many fan coil units in a building, one fan coil system can be specified and separate FOR ZONE specifications giving the supply air volume for each of the separate fan coil units can be input instead of simulating many separate fan coil systems. If the user wants to simulate more than one zone on a single fan coil system, he/she should be certain that:

1. All the parameters discussed above are identical or nearly identical for each fan coil in the system except SUPPLY AIR VOLUME. Fan coils in different zones of different sizes can be simulated merely by specifying the different supply air volumes for each zone, providing the fan coil characteristics for each fan coil are roughly the same. If more than one size unit is to be simulated per system, the heating coil capacity specified in OTHER SYSTEM PARAMETERS should be given for the largest unit. Note that by using this approach unmet loads will not be reported unless the heating and/or cooling is off.

2. The above parameters are specified for a single fan coil unit; i.e., the total fan pressure is the total pressure dropped through one fan coil unit, not the sum of all pressure drops.

3. If the system operation is INTERMITTENT, all the fans in all the zones will run any time one of the zones has a load. The coils for each fan coil will only be energized, however, if the zone in question has a load.

DX Condensing Unit

DX CONDENSING UNIT PARAMETERS and their defaults are shown below. Names in parentheses on the right are variable names used in the equations that follow.

```
DX CONDENSING UNIT PARAMETERS:
    DX CONDENSING UNIT CAPACITY = 487.3;                                  (NOMCAP)
    DESIGN SATURATED SUCTION TEMPERATURE = 40; (4.4°C)                    (DSST)
    DESIGN SATURATED CONDENSING TEMPERATURE = 122; (50°C)                 (DSCT)
    MINIMUM SATURATED CONDENSING TEMPERATURE = 100; (37.8°C)              (MSCT)
    UNLOADER THROTTLING RANGE = 4; (2.2°C)                                (UTR)
    CONDENSER UA = 27.43; (14.5 kW/°C)                                    (CUA)
    SCT TEMPERATURE RISE = 2.63; (1.4°C)                                  (SCTTR)
    DESIGN FULL LOAD POWER RATIO = .326                                   (DFLPR)
    RCAVCD (.9980,-0.0229,.0003);        (RCAVCD(1),RCAVCD(2),RCAVCD(3))
    RPWRCD (.1456,.9554,-.10476);        (RPWRCD(1),RPWRCD(2),RPWRCD(3))
    ADJECD  (.2984,.1334,34.603);        (ADJECD(1),ADJECD(2),ADJECD(3))
END CONDENSING UNIT PARAMETERS;
```

General

BLAST uses the above parameters in the following way:

Estimate SST: SST = DSST - CPLR * UTR

where:
SST is the actual saturated suction temperature
CPLR is the cooling part-load ratio, calculated by coil modeling
DSST is the design saturated suction temperature
UTR is the unloader throttling range.

Estimate SCT: $$SCT = MAX\left(MSCT, OADB + \frac{LOAD * (1 + DFPLR)}{CUA}\right)$$

where:
SCT is the actual saturated condenser temperature
OADB is the outdoor dry bulb temperature
LOAD is the total load on condensing unit calculated by coil modeling
MSCT is the minimum saturated condensor level
DFPLR is the design full-load power ratio
CUA is condensor U-factor-area product.

Determine equivalent temperature difference (ΔT):

$$\Delta T = (SCT - DSCT)/SCTTR - (SST - DSST)$$

where:
DSCT is the design saturated condensing temperature
SCTTR is the SCT temperature rise

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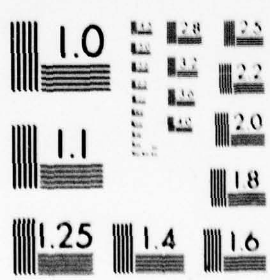


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Calculate available capacity (AVAIL CAP):

$$AVAILCAP = NOMCAP * RCAVCD\,(1) + RCAVCD\,(2)\,\Delta T + RCAVCD\,(3)\,\Delta T^2)$$

where: NOMCAP is the user-specified cooling capacity of the DX coil being served by the condensing unit

Compute Carnot efficiency:

$$\eta_c = \frac{SCT - SST}{SCT + T_{BASE}}$$

where: the addition of T_{BASE} makes the denominator degrees absolute °R or °K.

Compute actual full-load power ratio (FLPR):

$$FLPR = DFLPR * (ADJECD\,(1) + ADJECD\,(2)\,\eta_c + ADJECD\,(3)\,\eta_c^{\,2})$$

Compute part-load ratio (PLR):

$$PLR = \frac{LOAD}{AVAIL\ CAP}$$

Compute fraction of full-load power (FFL):

$$FFL = RPWRCD\,(1) + RPWRCD\,(2)\,PLR + RPWRCD\,(3)\,PLR^2$$

Compute power consumed:

$$Power = (AVAIL\ CAP) * (FLPR) * (FFL)$$

Example

The SST is estimated by dividing the total cooling load on the cooling coil by the total design capacity of the cooling coil. This coil part-load ratio (CPLR) is used with the unloader throttling range (UTR) and the DSST according to the following:

$$SST = DSST - CPLR * UTR \qquad [Eq\ F1]$$

For example, if the DSST is 40°F (4°C), the coil is operating at 60 percent capacity, and the unloader throttling range is 4°F (-15°C), the estimated actual saturated suction temperature is:

$$SST = 40 - .6 * 4 = 37.6°F\ (.55°C)$$

To estimate SCT, use CUA, OADB, LOAD, and DFLPR. The DFLPR is the inverse of coefficient of performance and is the dimensionless ratio of power supplied to the compressor divided by cooling effect supplied by the condensing unit. Thus, the heat rejected to the condenser is (as a first estimate):

$$Qc = LOAD + DFLPR * LOAD = CUA * (SCT - OADB) \qquad [Eq\ F2]$$

Note that DFLPR times LOAD is an estimate of the power into the compressor which must be rejected along with the cooling effect (the load). (A more refined estimate will be made later when power requirements are more precisely calculated.) Rearranging the Eq F2 yields:

$$SCT = OADB + \frac{Qc}{CUA} \qquad \text{[Eq F3]}$$

Additionally, SCT is constrained so as not to be lower than the minimum saturated condensing temperature (MSCT).

The condenser U-factor-area product (CUA) is a user-supplied or default parameter which can be calculated from full-load catalog data by writing the approximate heat balance of Eq F2 as:

$$Qc = LOAD + DPOWER = CUA\,(SCT - OADB)$$

where: DPOWER is the specified power input to the compressor.

The log-mean temperature difference could also be used in this equation; however, this approximation is used to define an effective UA based on inlet air temperature.

Since full load data are usually used, load becomes the capacity of the unit at specified OADB and SST. An average UA can be computed for several data points as shown below (Table F1 provides basic catalog data):

$$UA = \frac{NOM\ CAP + DPOWER}{SCT - OADB}\ (\text{kBtu/hr} - {}^{\circ}\text{F})^{*} \qquad \text{[Eq F4]}$$

Table F1
Performance Data

CONDENSING UNIT CAPACITIES

SST*	TEMP AIR ENTERING CONDENSER (F)														
	85			95			100			105			115		
(F)	Cap.	SCT	kW	Cap.	SCT	kW	Cap.	SCT	kW	Cap.	SCT	kW	Cap.	SCT	kW
30	501	109	47.7	463	118	48.0	444	122	49.2	426	127	50.3	391	136	52.4
35	553	111	48.4	512	120	50.9	492	124	52.2	472	129	53.5	434	138	55.8
40	607	114	51.0	563	122	53.8	542	127	55.3	521	131	56.7	480	140	59.3
45	664	116	53.7	618	125	56.8	595	129	58.3	573	133	59.9	528	142	62.8
50	723	119	56.4	673	127	59.8	650	131	61.4	626	136	63.1	578	144	66.3

*Or kW/°C

Several catalog points produce the following UA estimates:

$$UA = \frac{501 + 45.7 \times 3.412}{109 - 85} = 27.63$$

$$UA = \frac{563 + 53.8 \times 3.412}{122 - 95} = 27.65$$

$$UA = \frac{650 + 61.4 \times 3.412}{131 - 100} = 27.73$$

$$UA = \frac{426 + 50.3 \times 3.412}{127 - 105} = 27.16$$

$$UA = \frac{480 + 59.3 \times 3.412}{140 - 115} = 27.29$$

SST and SCT can now be estimated. The capacity of the condensing unit is estimated next since it varies with SST and SCT. On the basis of the ratio of the load on the condensing unit-to-the capacity of the unit, the part-load power consumption can be estimated.

The capacity of the unit is estimated in two steps. First an equivalent temperature difference, ΔT, is defined as:

$$\Delta T = (SCT - DSCT)/SCTTR - (SST - DSST) \qquad \text{[Eq F5]}$$

where: SCTTR is the number of degrees that SCT deviates from DSCT for each degree SST deviates from DSST while maintaining the nominal condensing unit capacity.

SCTTR can be determined by selecting two or more operating points where the unit operates at nominal capacity. One point is the design point. Using interpolation and Table F1, the following table can be constructed for a condensing unit with 563,000 Btu/hr nominal capacity at DSST = 40 and DSCT = 122.*

Table F2
Data for Calculating SCT Temperature Rise

Capacity (Btu/hr)	SST (°F)	SCT (°F)
563,000	40	122
563,000	45	135

$$SCTTR = (SCT - DSCT)/(SST - DSST)$$
$$= (135 - 122)/(45 - 40) = 2.60$$

Since SCTTR is expected to be independent of the selected design point, any other design point should produce the same value. For example, from Table F1, the capacity is 501,000 as DSST = 30, DSCT = 109. Using this as the design point:

*Metric conversion factors: 1 Btu/hr = .293 W; °C = (°F - 32) × 5/9.

Table F3
Data Used to Check SCT Temperature Rise

Capacity (Btu/hr)	SST (°F)	SCT (°F)
501,000	30	109
501,000	35	122.2
501,000	40	135.4

$$\text{SCTTR} = \frac{122.2 - 109}{35 - 30} = 2.64$$

$$\text{SCTTR} = \frac{135.4 - 109}{40 - 30} = 2.64$$

The average value for SCTTR is 2.63.

Condensing units usually operate at other than nominal capacity ($\Delta T \neq 0$). The second step in determining the actual capacity is to use the calculated value for ΔT and the empirical coefficients called RCAVCD parameters to adjust the nominal capacity according to the following:

$$\text{AVAIL CAP} = \text{NOM CAP} * (A_1 + A_2\Delta T + A_3\Delta T^2) \qquad \text{[Eq F6]}$$

where: A_1, A_2, and A_3 are the empirical RCAVCD parameters.

Curve-fitting procedures can be used to establish A_1, A_2, A_3 by fitting AVAIL CAP/NOM CAP to ΔT. (See Table F4 and Figure F1.)

Various SCTs and SSTs are calculated because only one part-load performance curve is used regardless of the SCT and SST. To use only one curve, the condensing unit part-load ratio (PLR) is defined as the ratio of load to *actual* capacity. Actual power consumption will be determined by multiplying full-load power consumption by a part-load correction factor (FFL), which is a function of PLR. The full-load power consumption is determined first, however, since it will vary from the nominal as the suction and condensing temperatures change.

Table F4
Data for Computing RCAVCD Coefficients

SCT	SST	Nominal Capacity = 563,000 Btu/hr AVAIL CAP/NOM CAP	ΔT
109	30	.89	5.05
111	35	.98	.81
114	40	1.08	-3.05
116	45	1.18	-7.28
119	50	1.28	-11.14
122	30	.79	10.00
124	35	.87	5.76
127	40	.96	1.90
129	45	1.05	-2.34
131	50	1.15	-6.57
136	30	.69	15.33
138	35	.77	11.09
140	40	.85	6.85
142	45	.94	-1.62

$$\frac{\text{AVAIL CAP}}{\text{NOM CAP}} = 0.9980 + (-0.0227)\,\Delta T + 0.0003\,\Delta T^2$$

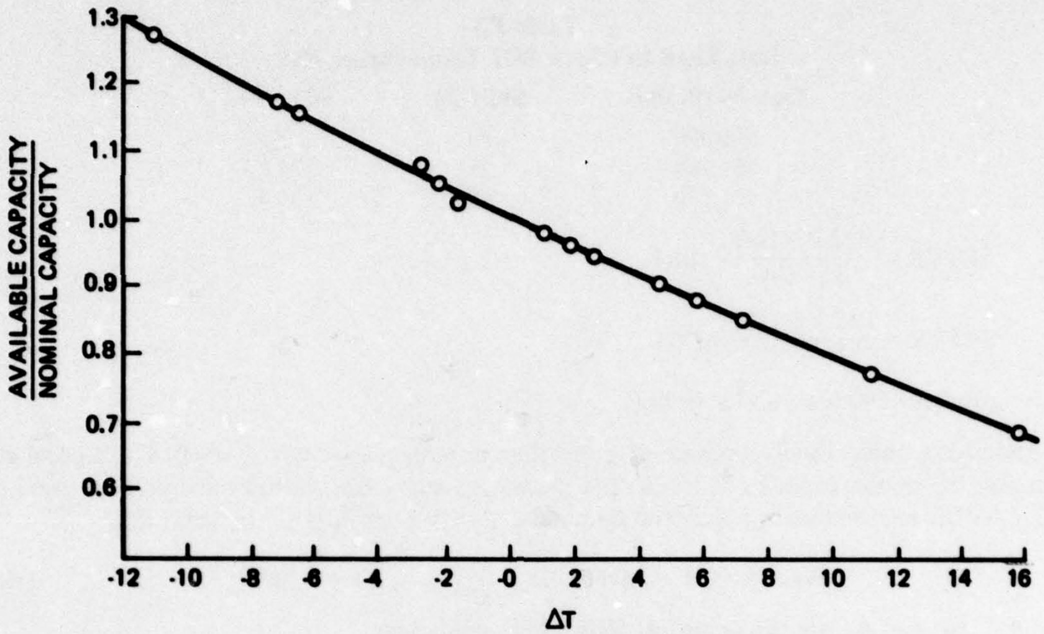


Figure F1. AVAILABLE CAPACITY/NOMINAL CAPACITY vs ΔT from Table F4.

A convenient way to consider power in modeling a condensing unit is to consider the power ratio, which is the ratio of power in-to-cooling effect produced. A further normalization occurs by dividing by the nominal power ratio. For the full-load condition, the full-load power ratio, FLPR, the nominal full-load power ratio, DFLRP, and the ratio of the two are used. Note the FLPR is the inverse of COP, and that since DFLPR is a constant (the full-load power ratio at the nominal condensing unit capacity), the ratio FLPR/DFKPR is proportional to COP. It has been shown that even though the refrigeration cycle is not a Carnot-cycle, the COP of the actual cycle can be related to the theoretical Carnot efficiency. That is:

$$\frac{\text{FLPR}}{\text{DFLPR}} = A_1 + A_2\eta_c + A_3\eta_c^{\,2} \qquad \text{[Eq F7]}$$

where: η_c = Carnot cycle efficiency operating between SCT and SST and A_1, A_2, A_3 are empirical coefficients (ADJECD).

If SCT and SST are in °F, then

$$\eta_c = \frac{\text{SCT} - \text{SST}}{\text{SCT} + T_{BASE}} \qquad \text{[Eq F8]}$$

where: the addition of T_{BASE} makes the denominator degrees absolute (°R or °K)

Table F5 was constructed to find A_1, A_2, and A_3.

Table F5
Data for Determining ADJECD Coefficients

DFLPR = .326

SST	SCT	η_c	Capacity (1000 Btu/hr)	Power (kW)	FLPR / DFLPR
30	109	.139	501	45.7	.955
35	111	.133	553	48.4	.916
40	114	.129	607	51.0	.879
45	116	.123	664	53.7	.846
50	119	.119	723	56.4	.816
30	122	.158	444	49.2	1.760
35	124	.152	492	52.2	1.110
40	127	.148	542	55.3	1.068
45	129	.143	595	58.3	1.025
50	131	.137	650	61.4	.989
30	136	.178	391	52.4	1.402
35	138	.172	434	55.8	1.345
40	140	.167	480	59.3	1.293
45	142	.161	528	62.8	1.245
50	144	.156	578	66.3	1.200
40	122	.141	563	53.8	1.000
		2.356			17.249

After curve-fitting: $\frac{FLPR}{DFLPR} = 0.2984 + 0.1334\eta_c + 34.603\eta_c^2$ (see Figure F2)

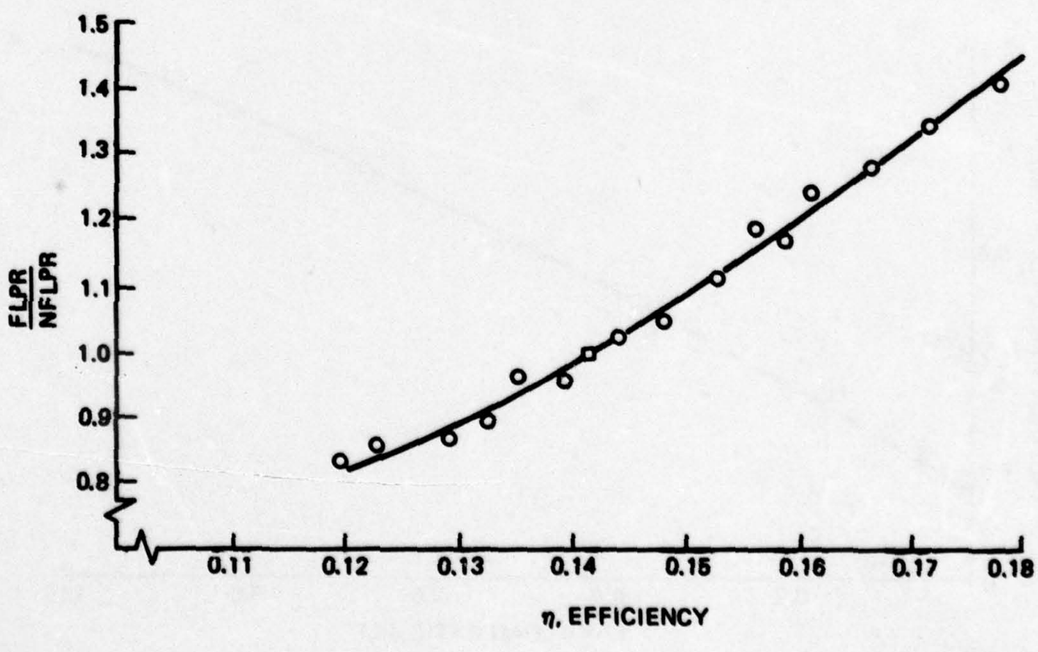


Figure F2. Dimensionless Full-Load Power vs Carnot Efficiency from Table F5.

The last step in determining part-load performance coefficients which relate the fraction of full-load power to the PLR is:

$$FFL = A_1 + A_2\,(PLR) + A_3\,(PLR)^2$$

where: FFL is the fraction of full-load power

PLR is the part-load ratio on the condensing unit (LOAD/AVAIL CAP)

A_1, A_2, A_3 are coefficients of the RPWRCD set.

Table F6 lists data showing the compressor performance under part-load conditions.

Table F6
Data for Determining RPWRCD Coefficients

FFL	PLR
1.00	1.0
.86	.833
.74	.666
.60	.500
.45	.333

After curve-fitting: $FFL = 0.1456 + 0.9554\,(PLR) + (-0.10476)\,(PLR)^2$ (See Figure F3)

Note that even though the compressor unloads in "steps," if the PLR does not correspond exactly to an unloading point, the compressor will cycle between steps and the *FFL will closely* follow the smooth curve shown in Figure F3. For example, if the PLR for a given hour is 0.75,

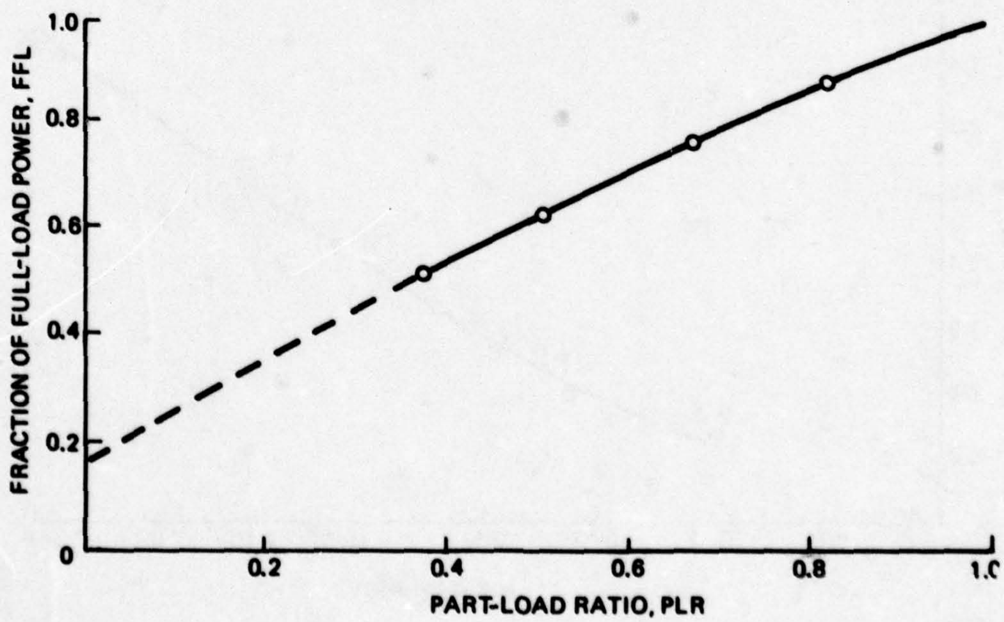


Figure F3. Part-Load Performance Curve from Table F6.

then, for the above data, the compressor will operate at 0.833 part load for 50.3 percent of the hour, and at 0.666 part load 49.7 percent of the hour. It will consume about 80.3 percent of the FFL.

Power consumption is:

$$\text{Power} = (\text{AVAIL CAP}) * (\text{FLPR}) * (\text{FFL}).$$

DX Packaged Unit

For a DX PACKAGED UNIT system, the necessary coil parameters with the English defaults are:

```
COOLING COIL DESIGN PARAMETERS:
    DXCOIL1(4589.44, 1.63, -.02022)
    DXCOIL2(-25.342, .02492, .000461)
    DXCOIL3(.01715, -.000051, -1.71E-8)
END COOLING COIL DESIGN PARAMETERS;
```

These parameters are used in the following curve fit:

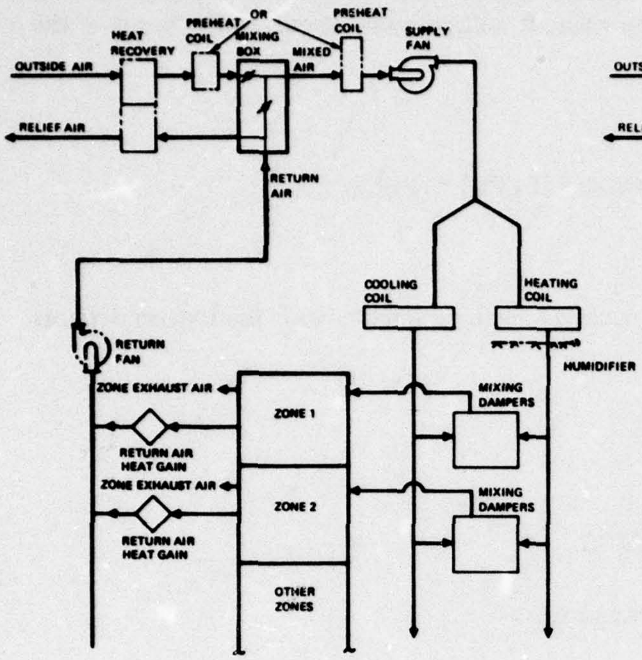
$$\begin{aligned} QSQT = {} & DXCOIL1(1) + DXCOIL2(2) * EADB \div DXCOIL1(3) * EADB^2 \\ & + DXCOIL2(1) * EAWB + DXCOIL2(2) * EADB * EAWB \\ & + DXCOIL2(3) * EADB^2 * EAWB + DXCOIL3(1) * EAWB^2 \\ & + DXCOIL3(2) * EADB * EAWB^2 + DXCOIL3(3) * EADB^2 * EAWB^2 \end{aligned}$$

where: QSQT = current hour sensible cooling load/current hour total load
EADB = current hour dry bulb air temperature entering DX coil in absolute degrees (°R or °K)
EAWB = current hour wet bulb air temperature entering DX coil in absolute degrees (°R or °K)

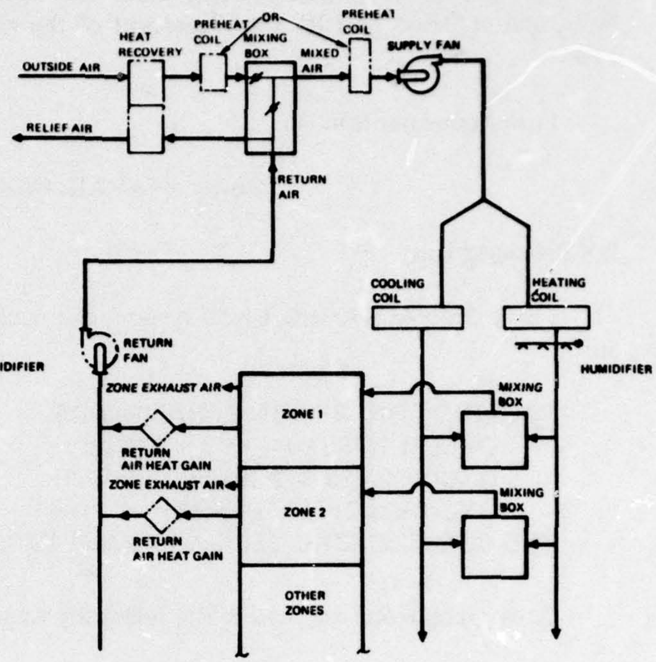
Computer service bureaus have "canned" regression curve fitting routines which can be used to determine the above parameters from catalog data.

Fan System Diagrams

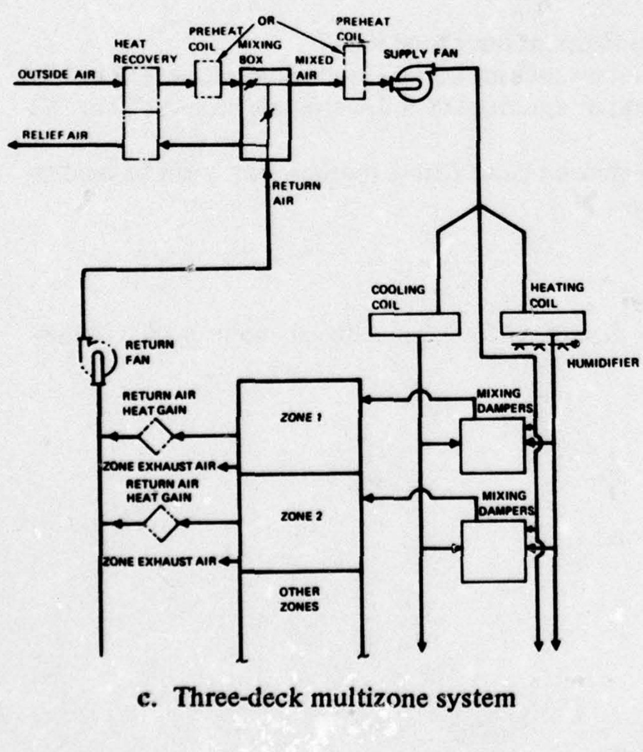
Diagrams for each of the fan system types that BLAST can simulate are shown on the following pages (Figures F4, F5, and F6).



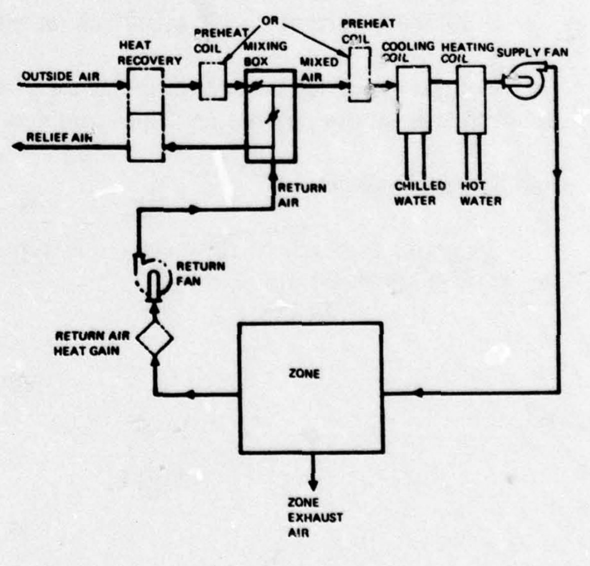
a. Multizone system



b. Dual-duct system (same as multizone in BLAST simulation)

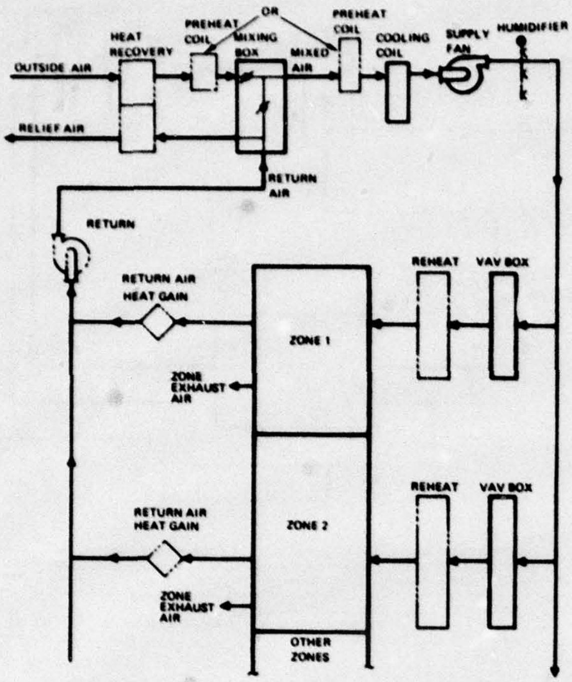


c. Three-deck multizone system

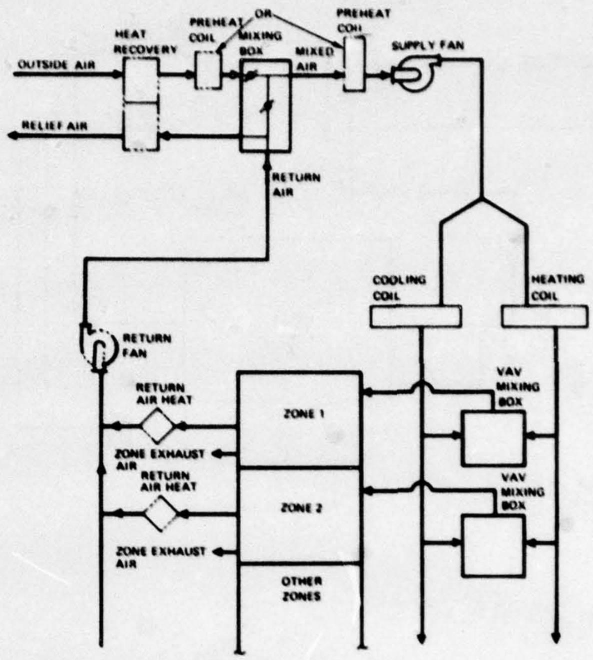


d. Single-zone drawthrough system

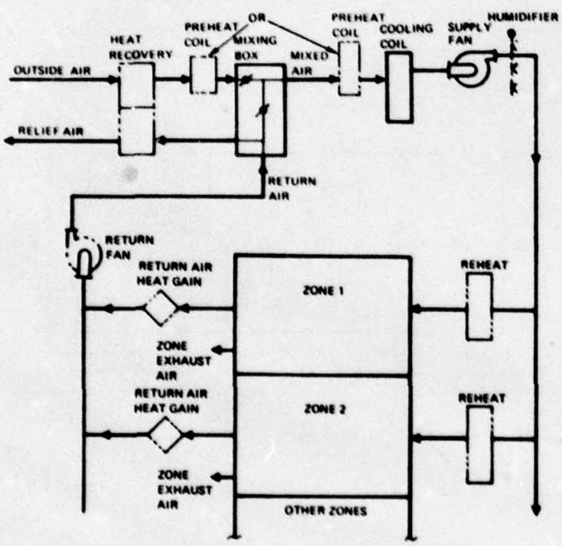
Figure F4. Multizone, dual-duct, three-deck multizone, and single-zone drawthrough systems.



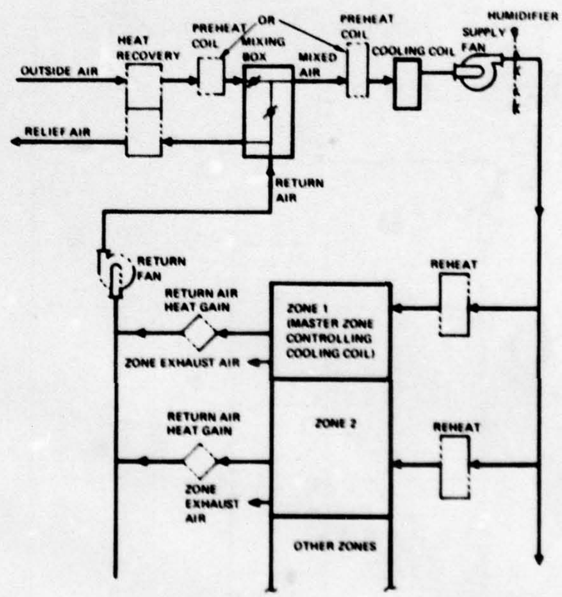
a. Variable volume system



b. Dual-duct variable volume system

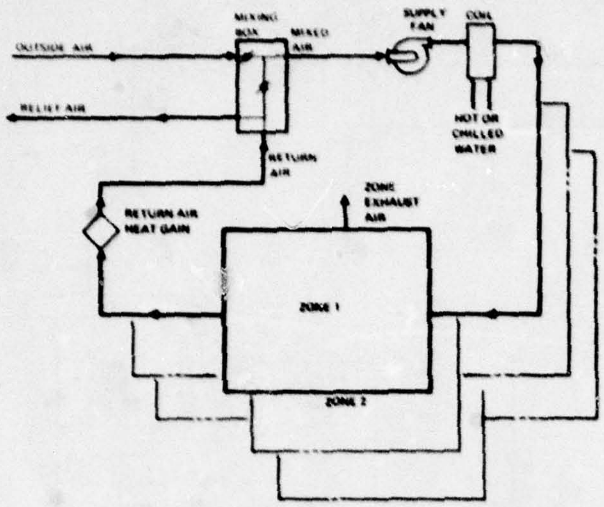


c. Terminal reheat system

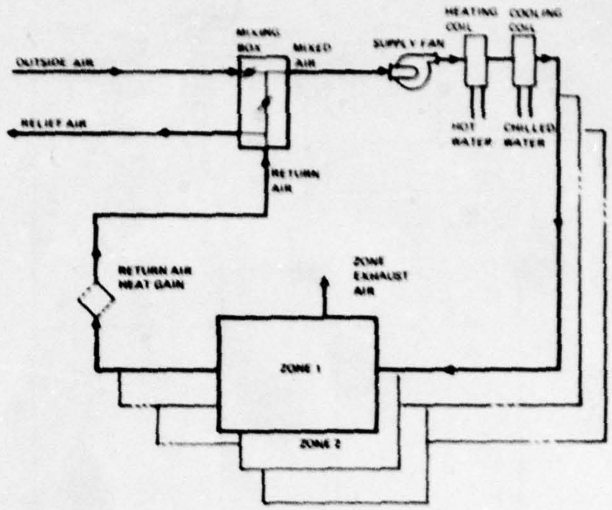


d. Subzone reheat system

Figure F5. Variable volume, dual-duct variable volume, terminal reheat, and subzone systems.



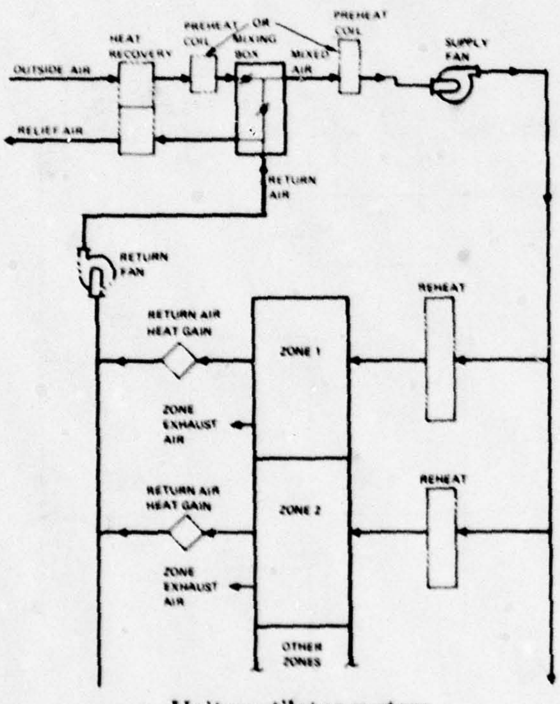
a. Two-pipe fan coil system



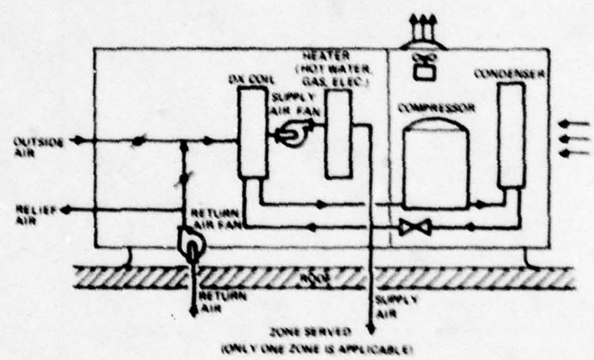
NOTES

- HEAT RECOVERY, PREHEAT AND PREHEAT COIL LOCATION ARE ALL OPTIONAL
- MORE THAN ONE SYSTEM CAN BE SERVED BY ONE FAN COIL SIMULATION PROVIDED CERTAIN CONDITIONS ARE MET IN THE PHYSICAL SYSTEM
- ZONES SERVED BY FAN COIL SYSTEM MAY NOT HAVE ZONE EXHAUST
- ECONOMY COPIES ARE NOT ALLOWED FOR FAN COIL SYSTEMS
- THE COOLING COILS ARE ASSUMED CHILLED WATER REGARDLESS OF COIL TYPE = SPECIFICATION

b. Four-pipe fan coil system



c. Unit ventilator system



d. DX Packaged Unit system

Figure F6. Two- and four-pipe fan coil, unit ventilator, and DX Packaged Unit systems.

APPENDIX G: CENTRAL PLANT MODELS*

Equipment Allocation

Default Operating Rules

The user may specify operating rules for allocating each type of equipment to meet different load ranges. If *not* specified, default rules will assign equipment in a fashion designed to approach the optimum operating point for each component type. In addition, default or user-specified "best" operating points are given for each component. These values are used to determine the near-optimum equipment loading. If this default load allocation strategy will *not* be used, then the *specific* control strategy to be used should be specified in the EQUIPMENT ASSIGNMENT block.

The following example shows how gas turbine equipment is allocated by the default operating rules to meet an electrical demand of 3750 kBtu/hr. The equipment selection block is:

```
EQUIPMENT SELECTION:
    3 GAS TURBINE OF SIZE 1000 (2 AVAILABLE);
    1 GAS TURBINE OF SIZE 5000;
END EQUIPMENT SELECTION;
```

Assume that gas turbine generators operate BEST (most efficiently) at 60 percent of full load and that 1000- and 5000- kBtu/hr units will be used. The allocation algorithm first computes the best capacity to apply if units of the appropriate size are available, i.e., 3750/.6 or 6250 kBtu/hr. The total available capacity is 7000, which is +750 from the optimum. The algorithm next subtracts one unit of the *first size* specified from the available capacity (i.e., one 1000 kBtu/hr unit), leaving 6000 available. This available capacity is −250 from the optimum, which is closer to the optimum than the availability of 7000 kBtu/hr. Therefore (providing the demand does not overload the equipment as it does not in this case), 6000 kBtu/hr capacity will be made available to meet the 3750 kBtu/hr load with one 5000 kBtu/hr unit and one 1000 kBtu/hr unit sharing the load in proportion to their individual capacities. The operating load ratio will be 0.625.

If the user had specified a 5000 kBtu/hr unit first and then the two 1000 kBtu/hr units, the default operating rule would allocate 7000 kBtu/hr of capacity at an operating ratio of 0.536 (not only would subtraction of the first specified 5000 kBtu/hr unit result in an overload, but 2000 is clearly further from the optimum of 6250 than is 7000). This illustrates the importance of the order in which unit sizes are specified.

If computed results are to have meaning, actual systems either being designed or which presently exist must be capable of being controlled in the same fashion as simulated.

Sequencing Rules

A few other default operating rules pertaining to sequence of equipment types are also part of central plant simulation. The heat energy demands and supplies in the plant are divided into five categories according to the "level" of energy required. Level 5 is the highest quality required.

*The numerical values used in this appendix are in English units, and will not be the same as the SI unit default values. Metric conversion: 1 kBtu/hr = .293 kW.

Table G1
Energy "Levels" and Corresponding Demand and Supply

Level	Demand
5	Two-stage absorber
4	One-stage absorber
3	Space heating
2	Domestic hot water heating
1	Make up water preheat

Level	Supply (from Waste Heat)
5	Exhaust heat from diesel, gas turbine, and steam turbine
4	Diesel jacket heat and solar heat for cooling (above TMINC)
3	Recovered heat from double bundle and heat pump and solar heat for heating (above TMINH)
2	Lube heat and solar heat for domestic hot water (below TMINH)
1	None

The waste heat supplies are used to meet demands at their level on any lower level. Any heating demands which cannot be met by waste heat are loads on the boiler.

If, for example, Level 3 energy is demanded, it can be supplied only by Levels 3, 4, and 5, successively.

If the amount of Level 5 waste heat supply exceeds the amount of the Level 5 demand, and if all other lower level demands are satisfied, heat can be stored for that hour if a hot storage tank is specified. (Only Level 5 heat will be stored in a HOT STORAGE TANK specified under EQUIPMENT SELECTION.)

If the hot storage tank becomes charged to capacity, or is not specified, then cold storage can be done from the surplus Level 5 heat. To allow the cold storage, the user must specify both a cold storage tank and an absorption chiller. (Only excess Level 5 heat can be used to make "cold.") The hot and cold stored energy are then used to offset the space heating and cooling loads, respectively, in later hours.

The solar energy storage tank is *completely separate* from the other hot storage tanks (if any). It stores collected solar heat only. Heat from the solar tank is used to meet Level 4 demands (one stage absorber) as long as the solar tank temperature remains above TMINC. Level 3 demands (heating) are met as long as the tank is hotter than TMINH. Heat pump false loading can be accomplished as long as the tank is above TMINHP.

In addition to the energy level rules above, BLAST generally allocates the most efficient devices to meet demands. Thus, diesel generators (if specified) are allocated before steam turbines (if steam turbines are selected) which are allocated before gas turbines (if any gas turbines are selected).

Heat pumps are always allocated before double-bundle chillers and double-bundle chillers are always used before simple compression chillers whenever there is a demand for heat (otherwise they are not). Unless waste heat is available, compression chillers are always used before absorbers, if

both are selected. If waste heat (from solar or engines) is available, absorbers are allocated first up to a capacity corresponding to the amount of waste heat available or the total absorber capacity available, whichever is smaller. Compression chilling is used to meet the remaining load, if any. Note that if engine generators are used, more waste heat is available as the compression chiller load increases. Thus, chilled water demands are automatically divided between compression and absorption chillers so that as much of the waste heat as possible is used to accomplish "free" cooling. This strategy corresponds to a series piping arrangement where absorbers are used to precool the chilled water before it enters the compression chiller. If no waste heat is available, compression chillers are used up to their installed capacity and then absorbers, if installed, are used with heat produced by a boiler. If the generating capacity of a plant is exceeded, purchased power is used.

Equipment Performance Parameters

Although there are generic models for each central plant component in the BLAST program, users may supply specific component performance coefficients to override these defaults and model one or more products of a particular manufacturer. The syntax for changing the defaults is:

```
EQUIPMENT PERFORMANCE PARAMETERS:
     (parameter name) (usn1, usn2, usn3);
     (other parameter name) (usn4, usn5, usn6);
.
.
.
END EQUIPMENT PERFORMANCE PARAMETERS;
     (END; is equivalent)
```

The meaning of each equipment performance parameter is discussed below. In general, components are modeled by the use of quadratic equations or products of quadratic equations of the form $Y = usn1 + usn2 * X + usn3 * X^2$. This is particularly convenient, since most manufacturers present the data on component performance as one-dimensional curves or tables where all variables except one are fixed. Dimensionless ratios are used whenever possible. Note that only one group of parameter sets (one model) is used for each component type, regardless of the number of different sizes selected.

Table G2 summarizes the **EQUIPMENT PERFORMANCE PARAMETERS** and gives their default parameters. Each of these sets of parameters will be discussed in detail in the paragraphs that follow. Curve-fitting methods used to obtain the parameters will not be discussed in detail, since many programmable calculators and almost all computer centers have program packages for doing these simple curve fits. The formula for parabolic curve fitting can be found in any good statistics text.*

Table G3 indicates which **EQUIPMENT PERFORMANCE PARAMETERS** apply to each central plant component.

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*For example, A. M. Wood and F. A. Graybill, *Introduction to the Theory of Statistics* (McGraw-Hill, 1963).

Table G2
Equipment Performance Coefficients

CERL -- B.L.A.S.T. SYSTEM --- VERSION 2.0   12 JUN 79   06.25.07

EQUIPMENT PERFORMANCE COEFFS (EP) DATA   VALUE(ENGLISH)

CODE	NAME	COEFF 1	COEFF 2	COEFF 3
CAVL1A	CAPACITY RATIO VS GEN TEMP (1S ABSOR	1.00000000	-.01611111	0.
REN1A	ENERGY I/O COEF (1-STG ABS CHILR)	.19100000	.91000000	.38800000
REN2A	ENERGY I/O COEF (2-STG ABS CHILR)	.11467000	.67212000	.21212000
REN2AE	ENERGY I/O COEF (2-STG ABS CHILR W ECON.	.12917000	.36902000	.51136000
RCAVHP	AVAILABLE CAPACITY RATIO (HEAT PUMP)	1.00600000	-.01900000	.00022006
RPWR1C	ENERGY I/O COEFF (HERMETIC COMPR CHILR)	.16017000	.31644000	.51894000
RPWR2C	ENERGY I/O COEFF (OPEN CENT COMPR CHILR)	.23900000	-.04045000	.79545000
RPWR3C	ENERGY I/O COEFF (RECIPROC COMPR CHILR)	.14940000	.95680000	-.11164000
RCAVDB	AVAILABLE CAPACITY RATIO (DBL BUNDLE)	1.00600000	-.01900000	.00022006
RPWRDB	ENERGY I/O COEFF (DBL BUNDLE)	.16017000	.31644000	.51894000
ADJTDB	CONDENST COOLNG WTR TEMP ADJ(DBL BUNDLE)	95.00000000	1.19000000	43.98800000
ADJEDB	ENERGY RATIO ADJSMNT FACTOR (DBL BUNDLE)	3.15800000	-3.31300000	1.15400000
RELD	POWER OUT / FUEL INPUT COEFF (DIESEL)	.09755000	.63180000	-.41650000
RJACD	JACKET HEAT/ FUEL INPUT COEFF (DIESEL)	.39220000	-.43670000	.27796000
RLUBD	LUBE HEAT / FUEL INPUT COEFF (DIESEL)	.08830000	-.13710000	.08030000
REXD	EXHAUST HEAT/FUEL INPUT COEFF (DIESEL)	.31440000	-.13530000	.09726000
TEXD	EXHAUST TEMP COEFF (DIESEL)	364.01111111	18.51833333	0.
FUEL1G	FUEL I/O COEFF 1-3 (GAS TURBINE)	9.41000000	-9.48000000	4.32060000
FUEL2G	FUEL I/O COEFF 4-6 (GAS TURBINE)	1.00440000	-.00259200	0.
SOLAR	COLLECTOR PERFORMANCE COEFF (SOLAR)	.81300000	-.00205740	0.
FEXG	EXHAUST FLOW COEFF (GAS TURBINE)	15.63799955	-.09914400	-.00020000
TEX1G	EXHAUST TEMP COEFF 1-3 (GAS TURBINE)	283.02469136	95.06172839	24.69135802
TEX2G	EXHAUST TEMP COEFF 4-6 (GAS TURBINE)	1.00560000	.00583200	0.
ELUBG	LUBE OIL COEFF (GAS TURBINE)	.22300000	-.40000000	.22860000
RF1	RATING FACTOR TEMP COEFF 1- 3 (TOWER)	191.81550000	-2.18287800	.00059414
RF2	RATING FACTOR TEMP COEFF 4- 6 (TOWER)	230.53950000	-2.68801200	.00074907
RF3	RATING FACTOR TEMP COEFF 7- 9 (TOWER)	126.23490000	-1.45260000	.00040123
RF4	RATING FACTOR TEMP COEFF 10-12 (TOWER)	131.58000000	-1.54134000	.00043201
RF5	RATING FACTOR TEMP COEFF 13-15 (TOWER)	86.73600000	-1.00152000	.00027685
RF6	RATING FACTOR TEMP COEFF 16-18 (TOWER)	70.12800000	-.80937000	.00022401
RFUELB	ENERGY I/O COEFF (STEAM BOILER)	.60000000	.88888889	-.49382716
ADJTHP	CNDNSR COOLG WTR TMP (HEAT PUMP	95.00000000	1.19000000	43.98800000
ADJEHP	ENERGY RATIO ADJSMNTFCTR (HEAT PUMP)	3.15800000	-3.31300000	1.15400000
RPWRHP	ENERGY I/O COEFF (HEAT PUMP)	.16017000	.31644000	.51894000
RFSTUR	STEAM FLOW COEFF (STEAM TURBINE)	1.00000000	0.	0.
UACD	STACK U-FACTOR * AREA COEFF (DIESEL)	.03085547	.90000000	0.
UACG	STACK U-FACTOR * AREA COEFF (GAS TURB)	.06178827	.90000000	0.
RFR	RATING FACTOR RANGE COEFF (TOWER)	0.	.32400000	0.
HPUMP	HEATING PUMP POWER COEFFICIENTS	1.00000000	0.	0.
CPUMP	COOLING PUMP POWER COEFFICIENTS	1.00000000	0.	0.
TPUMP	C TOWER PUMP POWER COEFFICIENTS	1.00000000	0.	0.
ADJT1C	COND COOL WTR T ADJ (HRMTC COMPR CHILR)	95.00000000	1.19000000	43.98800000
RCAV1C	AVAIL CAPCTY RATIO (HRMTC COMPR CHILR)	1.00600000	-.01900000	.00022006
ADJE1C	ENGY RATIO ADJSTMNT (HRMTC COMPR CHILR)	3.15800000	-3.31300000	1.15400000
ADJT2C	COND COOL WTR T ADJ (OPN CENT CMPR CHLR)	95.00000000	1.19000000	43.98800000
RCAV2C	AVAIL CAPCTY RATIO (OPN CENT CMPR CHLR)	1.00600000	-.01900000	.00022006
ADJE2C	ENGY RATIO ADJSTMNT (OPN CENT CMPR CHLR)	3.15800000	-3.31300000	1.15400000
ADJT3C	COND COOL WTR T ADJ (RECIP COMPR CHILR)	95.00000000	1.19000000	43.98800000
RCAV3C	AVAIL CAPCTY RATIO (RECIP COMPR CHILR)	1.00600000	.00039611	0.
ADJE3C	ENGY RATIO ADJSTMNT (RECIP COMPR CHILR)	3.15800000	-3.31300000	1.15400000

Table G3
Performance Parameters for Various Equipment Types

Equipment Type

●Performance Parameters for each equipment type

Performance Parameter Name	DIESEL/GENERATOR	GAS TURBINE	HEAT RECOVERY	BOILER	ONE-STAGE ABSORBER	ONE-STAGE ABSORBER (Solar Driven)	TWO-STAGE ABSORBER	TWO-STAGE ABSORBER W/ECON	DOUBLE BUNDLE CHILLER	HEAT PUMP	CHILLER	OPEN CHILLER	RECIPROCATING CHILLER	SOLAR COLLECTORS	COOLING TOWERS	PUMPS
ADJEDB									●							
HP										●						
1C											●					
2C												●				
3C													●			
ADJTDB									●							
HP										●						
1C											●					
2C												●				
3C													●			
CAVL1A						●										
CPUMP					●	●	●	●	●	●	●	●	●			●
ELUBG		●														
FEXG		●														
FUEL1G		●														
2G		●														
HPUMP				●												●
RCAVDB									●							
HP										●						
1C											●					
2C												●				
3C													●			
RELD	●															
REN1A					●	●										
2A							●									
2AE								●								
REXD	●															
RFR															●	
RFUELB				●												
RF1															●	
2															●	
3															●	
4															●	
5															●	
6															●	
RJACD	●															
RLUBD	●															
RPWRDB									●							
HP										●						
RPWR1C											●					
2C												●				
3C													●			
SOLAR														●		
TEXD	●															
TEX1G		●														
2G		●														
UACD	●		●													
UACG		●	●													
TPUMP															●	●

Equipment Performance Parameters - Diesel Generator

Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS:
     .
     .
     .
     RELD (.Ø9755,.6318,-.4165);
     RJACD (.3922,-.4367,.27796);
     RLUBD (.Ø8Ø3,-.1371,.Ø8Ø3);
     REXD (.3144,-.1353,.Ø9726);
     TEXD (364.Ø,18.52,Ø.Ø);
     UACD (.Ø3Ø8,.9Ø, Ø.Ø);
     .
     .
     .
END;
```

General

Diesel engine generators are modeled using the following equations:

$$\text{Electric energy output/fuel energy input} = A_1 + A_2 \cdot PLR + A_3 \cdot PLR^2 \qquad \text{[Eq G1]}$$

where: PLR = part-load ratio (i.e., electric load/generator capacity)
A_1, A_2, and A_3 = equipment performance parameters of the RELD parameter set.

$$\text{Recoverable jacket heat/fuel energy} = B_1 + B_2 \cdot PLR + B_3 \cdot PLR^2 \qquad \text{[Eq G2]}$$

where: B_1, B_2, and B_3 = equipment performance parameters in the RJACD set.

$$\text{Recoverable lube oil heat/fuel energy input} = C_1 + C_2 \cdot PLR + C_3 \cdot PLR^2 \qquad \text{[Eq G3]}$$

where: C_1, C_2, and C_3 = equipment performance parameters in the RLUBD set.

$$\text{Total exhaust heat/fuel energy input} = D_1 + D_2 \cdot PLR + D_3 \cdot PLR^2 \qquad \text{[Eq G4]}$$

where: D_1, D_2, and D_3 = equipment performance parameters in the REXD set.

$$\text{Exhaust gas temperature/fuel energy input} = E_1 + E_2 \cdot PLR + E_3 \cdot PLR^2 \qquad \text{[Eq G5]}$$

where: E_1, E_2, and E_3 = equipment performance parameters in the TEXD set.

The diesel generator model uses the electrical load and engine generator size to compute part-load ratio (PLR). Eq G1 is then used to compute fuel energy input. Eqs G2 and G3 are used to compute recoverable jacket and lube oil heat. Finally, Eqs G4 and G5 are used with the U-factor-area product for the exhaust gas heat exchanger to compute the recoverable exhaust heat. The left sides of the equations indicate the manufacturer's curve or tables that must be obtained for diesel

engine generators to derive the equipment performance parameters. Note that simple transformation in the form of the manufacturer's curves may be required. For example, the data required to determine the RELD parameters set may be presented in the form of fuel consumption vs kilowatt electrical load. In this case, the transformation required is (K is the appropriate units conversion constant):

$$\frac{\text{(electrical load) (K)}}{\text{(fuel consumption) (heat content of fuel)}} = \frac{\text{electrical energy output}}{\text{fuel energy input}} \qquad \text{[Eq G6]}$$

and,

$$\frac{\text{electrical load}}{\text{generator capacity}} = \text{part-load ratio.} \qquad \text{[Eq G7]}$$

Example

The following example illustrates the procedure for generating performance coefficients for a specific diesel generator. In the example, data for a 630-kW ebullient diesel engine generator were obtained from the manufacturer (Table G4). The following equations were also obtained from the manufacturer:

$$\text{Lube heat (Btu/min)} = 8.4 \times \text{horsepower.} \qquad \text{[Eq G8]}$$

$$\text{Fuel consumption (Btu/min)} = 1.1\text{ (exhaust heat + jacket heat + lube heat + aux heat + work).} \qquad \text{[Eq G9]}$$

Table G4
Manufacturer's Data

Percent Load	Total Exhaust Gas Heat Rejected at 90°F (Btu/min)	Recoverable Exhaust Gas Heat at 300°F (Btu/min)	Jacket & Lube Heat (Btu/min)	Work (Btu/min)	Aux. Heat (Pumps, Fans) (Btu/min)
100	31,960	17,650	24,400	35,820	11,128
75	24,380	12,910	18,900	26,870	8,520
50	17,040	8,070	12,300	17,190	6,760
25	10,820	4,020	5,900	8,960	4,470

Step 1

Determine exhaust gas temperature. Although the exhaust gas temperature is not given, it can be determined from the following equations:

$$\text{Total exhaust gas heat at 90°F} = \dot{m}c_p\,(T_E - 90) \qquad \text{[Eq G10]}$$

$$\text{Recoverable exhaust gas heat of 300°F} = \dot{m}c_p\,(T_E - 300) \qquad \text{[Eq G11]}$$

where $\dot{m}$ = the exhaust gas mass flow rate
c_p = the exhaust gas specific heat
T_E = the exhaust gas temperature in °F.

After dividing and rearranging,

$$T_E = \frac{90(H_{300}) - 300(H_{90})}{H_{300} - H_{90}} \qquad \text{[Eq G12]}$$

where H_{300} = recoverable exhaust gas heat at $300^{o}F$
H_{90} = total exhaust gas heat at $90^{o}F$.

For example, at 100 percent load:

$$T_E = \frac{90(17650) - 300(31960)}{17650 - 31960} = 559^{o}F$$

Repeating the process using manufacturer's data for other PLRs gives the following results:

Table G5
Exhaust Gas Temperature for Various PLRs

Percent Load	PLR	Exhaust Gas Temperature	
100	1.0	$559^{o}F$	$1019^{o}R$
75	.75	$536^{o}F$	$996^{o}R$
50	.50	$489^{o}F$	$949^{o}R$
25	.25	$424^{o}F$	$884^{o}R$

Step 2

Determine exhaust gas heat. Note that exhaust gas heat is not equal to the total rejected heat at $90^{o}F$. The number required is the total number of Btu/min leaving the engine in the exhaust gas (since ratios will ultimately be used, it does not matter whether Btu/min or Btu/hr are used, as long as the same units are used consistently). This number equals $\dot{m}c_p\,(T_E - 32)$, since $32^{o}F$ is the base temperature for enthalpy calculations. Since T_E is known, only $\dot{m}c_p$ must be found in order to compute exhaust gas heat. The manufacturer's data can be used to do this by noting that total exhaust gas heat at $90^{o}F = \dot{m}c_p\,(T_E - 90)$. For example, for 100 percent load:

$$\dot{m}c_p\,(559 - 90) = 31{,}960$$

or

$$\dot{m}c_p = \frac{31{,}960}{559 - 90} = 68.14 \text{ Btu/min - }^{o}F$$

Repeating the process for other PLRs gives:

Table G6
Exhaust Gas Heat for Various PLRs

Percent Load	PLR	Exhaust Gas Heat (Btu/min)
100	1.0	35,912
75	.75	34,345
50	.50	31,142
25	.25	26,712

Step 3

Determine lube oil heat. The manufacturer indicates that lube heat is a linear function of load on the engine:

$$\text{Lube heat (Btu/min)} = 8.4 \cdot \text{kW} \cdot 1.34\ \text{HP/kW}$$

For the 630-kW generator set, this results in:

Table G7
Lube Heat for Various PLRs

Percent Load	PLR	kW Load	Lube Heat (Btu/min)
100	1.0	630	7091
75	.75	472	5313
50	.50	315	3546
25	.25	157	1767

Step 4

Determine jacket heat. The jacket heat is determined by subtracting the lube heat from Column 4 of the manufacturer's data:

Table G8
Jacket Heat for Various PLRs

Percent Load	PLR	Jacket Heat (Btu/min)
100	1.0	18,309
75	.75	13,587
50	.50	8,754
25	.25	4,133

Step 5

Determine fuel consumption. Having computed the exhaust heat, jacket heat, and lube heat using the auxiliary energy and work energy given by the manufacturer, the fuel consumption can be computed on the basis of the formula provided by the manufacturer:

$$\text{Fuel consumption} = 1.1\ (\text{exhaust heat} + \text{jacket heat} + \text{lube heat} + \text{aux heat} + \text{work}) \qquad \text{[Eq G9]}$$

The fuel consumed for various PLRs:

Table G9
Fuel Consumption for Various PLRs

Percent Load	PLR	Fuel Energy (Btu/min)
100	1.0	119,086
75	.75	97,498
50	.50	74,923
25	.25	50,646

Step 6

Normalize results. The various heat rates (jacket heat, lube heat, exhaust heat, electrical power) must be divided by the fuel input rate to get data into the form for curve fitting.

$$\text{Electrical power} = \text{kW} \times 3412\ \text{Btu/hr-kW}\ \frac{1\ \text{hr}}{60\ \text{min}} \qquad \text{[Eq G13]}$$

Table G10
Normalized Data

Part-Load Ratio	Exhaust Temperature °R	Electric Power (Btu/min)	Electric Power/Fuel Input Rate	Exhaust Heat Rate/Fuel Input Rate	Jacket Heat Rate/Fuel Input Rate	Lube Heat Rate/Fuel Input Rate
1.0	1019	35,820	.301	.302	.154	.060
.75	996	26,870	.276	.352	.139	.054
.50	949	17,910	.239	.416	.117	.047
.25	884	8,960	.177	.527	.082	.035

Summary

The results of least squares curve-fitting on the diesel generator examples are the complete parameter set:

```
RELD (.09975, .34860, -.14800);
RJACD (.03850, .19520, -.0800);
RLUBD (.021,.063,-024);
REXD (.660,-.601,.224);
TEXD (796,390,-168);
UACD (0, 0, 0);
```

The (0,0,0) values for UACD mean that no heat recovery is done on this example diesel generator exhaust gas; when no heat recovery is specified, BLAST will ignore REXD and TEXD. Refer to the **Equipment Performance Parameter-Heat Recovery** section in this appendix for a discussion of how to obtain the UACD parameter set.

Equipment Performance Parameters - Gas Turbine

Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS:
    .
    .
    .
    FUEL1G (9.41, -9.48, 4.32);
    FUEL2G (1.0044, -.0026, 0.0);
    TEX1G (283.0, 95.06, 24.69);
```

```
TEX2G (1.006, .0058, 0.0);
FEXG (15.63, -.099, -.0002);
ELUBG (.223, -4, .2286);
UACG (.0618, 0.9, 0.0);
.
.
.
END;
```

General

Gas turbine generators use the FUEL1G and FUEL2G performance parameter sets to compute fuel energy consumption as a function of part-load and ambient (entering) air temperature, respectively. The form of the model is:

$$\frac{\text{fuel energy input}}{\text{electric energy output}} = [A1 + A2 \cdot (PLR) + A3 \cdot (PLR)^2] \cdot [B1 + B2 \cdot (\Delta T) + B3 \cdot (\Delta T)^2] \qquad \text{[Eq G14]}$$

where: PLR = part-load ratio
$\Delta T = T_{air} - 77$, where 77°F (25°C) is the fixed rating point temperature at which the capacity of the engine is specified
A1, A2, and A3 = the FUEL1G parameters
B1, B2, and B3 = the FUEL2G parameters
(B1 is 1.0 or nearly 1.0.)

Exhaust gas temperature is computed in a similar fashion:

$$\text{Exhaust gas temperature, }^\circ R = (C1 + C2 \cdot PLR + C3 \cdot PLR^2) \cdot (D1 + D2 \cdot \Delta T + D3 \cdot \Delta T^2) \qquad \text{[Eq G15]}$$

where: PLR and ΔT are as previously defined
C1, C2, and C3 = the TEX1G parameter set
D1, D2, and D3 = the TEX2G parameter set.

The exhaust gas flow rate per unit capacity is computed as a function of the above ΔT as follows:

$$\frac{\text{exhaust gas flow rate (lb/hour)}}{\text{unit capacity (1000 Btu/hour)}} = (E1 + E2 \cdot \Delta T + E3 \cdot \Delta T^2) \qquad \text{[Eq G16]}$$

where: E1, E2, and E3 = the FEXG parameters.

Example

Table G11 was constructed from the manufacturer's data for a 2580-kW gas turbine generator. These data were also used to obtain the gas turbine default values.

Table G11
Gas Turbine Generator Data
(Output Capacity = 8800 $\times$ 10^3 Btu/hr)

Entering Air Temperature, T_{air} °F	45	45	45	77	77	77	80	80	80	100	100	100
$T_{air} - 77$	−32	−32	−32	0	0	0	3	3	3	23	23	23
Load $\cdot$ (10^3 Btu/hr)	9690	7270	4950	8800	6600	4400	8393	6295	4197	7847	5885	3924
Part-Load Ratio	1.10	.862	.562	1.0	.75	.5	.954	.715	.477	.892	.669	.446
Fuel Energy in (10^3 Btu/hr)	41400	33530	27180	37430	31200	25300	36460	30620	24850	34000	28800	23600
$\frac{\text{Fuel Input}}{\text{Energy Out}}$	4.27	4.61	5.49	4.25	4.73	5.75	4.34	4.86	5.92	4.33	4.89	6.01
Exhaust Gas Temperature °R (°F + 460)	1293	1173	1060	1305	1193	1091	1303	1200	1102	1320	1217	1123
$\frac{\text{Exhaust Gas Flow}}{\text{Unit Capacity}}$ $\frac{\text{(lb/hr)}}{\text{1000 Btu/hr}}$	16.41	16.41	16.41	15.68	15.68	15.68	15.50	15.50	15.50	14.83	14.83	14.83

To begin curve-fitting, take the fuel input to energy output ratio data at 77°F, where $\Delta T = 0$.

Table G12
Data for Determining FUEL1G Parameter Set

$\frac{\text{Fuel input}}{\text{Energy output}}$	PLR
4.25	1.00
4.73	.75
5.75	.50

After curve-fitting:

$$\frac{\text{fuel input}}{\text{energy output}} = 9.41 - 9.48 \cdot (\text{PLR}) + 4.32 \cdot (\text{PLR})^2$$

Thus, the FUEL1G parameters become:

```
FUEL1G (9.41, -9.48, 4.32);
```

To determine the adjustment factor for entering air temperature, first define

$$\text{PLRFAC} = 9.41 - 9.48 \cdot (\text{PLR}) + 4.32 \cdot (\text{PLR})^2 \qquad \text{[Eq G17]}$$

and then define

$$\frac{\text{fuel input}}{\text{energy output}} \cdot \frac{1}{\text{PLRFAC}} = \text{B1} + \text{B2} \cdot (\Delta T) + \text{B3} \cdot (\Delta T)^2 \qquad \text{[Eq G18]}$$

Table G13 shows the data necessary for curve-fitting.

Table G13
Data for Determining FUEL2G Parameter Set

$\frac{\text{Fuel Input}}{\text{Energy Output}} \cdot \frac{1}{\text{PLRFAC}}$	ΔT
1.014	-32
1.018	-32
1.008	-32
1.0	0
1.0	0
1.0	0
1.010	3
1.004	3
1.008	3
.986	23
.978	23
.995	23

After curve-fitting:

$$\frac{\text{fuel input}}{\text{energy output}} \cdot \frac{1}{\text{PLRFAC}} = 1.0044 - .0008 \cdot (\Delta T) + 0.0 \cdot (\Delta T)^2$$

Thus, FUEL2G (1.0044, -0.0008, 0.0); is the FUEL2G parameter set specification.

The same procedure is used for exhaust gas temperatures:

Table G14
Data for Determining TEX1G Parameter Set

Exhaust Gas Temperature at T_{air} = 77°F (T_{exh})	PLR
1305°R	1.0
1193	.75
1091	.50

After fitting:

$$T_{exh} \text{ at } T_{air} = 77°\text{F} = 917 + 308 \cdot (\text{PLR}) + 80 \cdot (\text{PLR})^2$$

or

TEX1G (917,308,80);

If PLRFAC = $917 + 308 \cdot (\text{PLR}) + 80 \cdot (\text{PLR})^2$

then

$$\frac{T_{exh}}{\text{PLRFAC}} = \text{D1} + \text{D2} \cdot (\Delta T) + \text{D3} \cdot (\Delta T)^2 \qquad \text{[Eq G19]}$$

can be used to create Table G15:

Table G15
Data for Determining TEX2G Parameter Set

$\frac{T_{exh}}{PLRFAC}$	ΔT
.956	-32
.957	-32
.950	-32
1.000	0
1.000	0
1.000	0
1.015	3
1.018	3
1.018	3
1.051	23
1.050	23
1.049	23

After fitting:

$$\frac{T_{exh}}{PLRFAC} = 1.0056 + .0018 \cdot (\Delta T) + 0.0 \cdot (\Delta T)^2$$

or,

TEX2G (1.0056, .00180, 0.0);

Finally, the ratio of exhaust flow rate to generator capacity must be computed as a function of ΔT.

Table G16
Data for Determining FEXG Parameter Set

$\frac{\text{exhaust gas flow (lb/hr)}}{\text{unit capacity (1000 Btu/hr)}}$	ΔT
16.41	-32
15.68	0
15.50	3
14.83	23

After fitting:

$$\frac{\text{exhaust gas flow (lb/hr)}}{\text{unit capacity (1000 Btu/hr)}} = 15.638 - 0.0306 \cdot (\Delta T) - 0.0002 \cdot (\Delta T)^2$$

or,

FEXG (15.638, -0.0306, -0.0003);

Summary

The entire gas turbine generator parameter set becomes:

FUEL1G (9.41, -9.48, 4.32);
FUEL2G (1.0044, -0.0008, 0);

```
TEX1G (917 ,308, 80);
TEX2G (1.0056, 0.0018, 0);
FEXG (15.638, -0.0306, -0.0002);
UACG (0, 0, 0);
```

where the (0, 0, 0) values for UACG mean that no heat recovery is done on the example gas turbine exhaust gas. BLAST will ignore TEX1G, TEX2G, and FEXG if no heat recovery is specified. Refer to the **Equipment Performance Parameter - Heat Recovery** section in this appendix for a discussion of how to obtain the UACG parameter set.

Equipment Performance Parameters - Heat Recovery Gas Turbine and Diesel Generator

Parameters and Default Values

For gas turbines:

```
EQUIPMENT PERFORMANCE PARAMETERS:
        .
        .          other gas turbine parameters
        .
        UACG (.0618,0.9,0.0);
        .
END;
```

For diesel generators:

```
        .
        .          other diesel generator parameters
        .
        UACD (.0308,0.9,0.0);
        .
END;
```

General

Both gas turbine and diesel engine exhaust gas heat recovery systems use basic heat exchanger effectiveness models to compute the temperature of the gas leaving the heat recovery device and the amount of heat recovered. Under the assumption that the $\dot{m}c_p$ for the water or steam to which the exhaust heat is being rejected is much larger than the $\dot{m}c_p$ product for the exhaust gas, the basic heat exchanger effectiveness relationships follow:

$$1 - \epsilon = \exp\left(\frac{-UA}{\dot{m}c_p}\right) \qquad \text{[Eq G20]}$$

and

$$\frac{T_{out} - T_{c\ in}}{T_{exh} - T_{c\ in}} = \exp\left(\frac{-UA}{\dot{m}c_p}\right) \qquad \text{[Eq G21]}$$

where:

ϵ	= heat exchanger effectiveness
$\dot{m}$	= exhaust gas mass flow rate in lb/hour
c_p	= specific heat of the exhaust gas (.24 Btu/lb)
UA	= U-factor-times area (A) of the heat exchanger
T_{out}	= temperature of the exhaust gas leaving the heat exchanger
T_{exh}	= temperature of the exhaust gas entering the heat exchanger
$T_{c\ in}$	= temperature of water entering the heat exchanger or steam saturation temperature in the heat exchanger (TSATUR of the SPECIAL PARAMETER set)
$\left(\frac{UA}{\dot{m}c_p}\right)$	= the number of heat transfer units (NTU).

The BLAST program permits the user to vary the UA product using the performance parameter sets UACG and UACD. UACG applies to gas turbine exhaust heat recovery, while UACD is for diesel engine exhaust recovery. Variations in the UA product are made to be functions of the engine generator unit capacity.

$$UA = A1 \cdot (CAP)^{A2} \qquad \text{[Eq G22]}$$

where: A1 and A2 = the first two coefficients of the UACD or UACG parameter sets (the third coefficient is not used)
CAP = the total installed engine capacity in kBtu/hr.

In computing A1 and A2, the equation can be written in linear form as:

$$\ln UA = \ln A1 + A2 \ln CAP \qquad \text{[Eq G23]}$$

Note that since capacity is given in kBtu/hr, the units for UA must be kBtu/hr - °F when determining A1 and A2.

Users who wish to change UA for use with only one capacity may wish to change only the appropriate A1 coefficient.

Users who wish to model specific heat exchangers should obtain the heat exchanger effectiveness data for various sizes of interest and use Eq G20 to find UA as a function of *engine* capacity ($\dot{m}c_p$ values should be those for the engines running at nominal capacity). Alternately, Eq G21 can be used when effectiveness is not given, but appropriate temperature data is available.

Summary

If heat recovery *is* to be used, UACG and UACD can be entered in their respective equipment performance parameter sets or defaults will be used. If heat recovery *is not* to be used, UACG and UACD must appear in their sets as:

```
UACG (Ø, Ø, Ø);
```

or

```
UACD (Ø, Ø, Ø);
```

Equipment Performance Parameters - Boiler

Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS
    .
    .
    .
    RFUELB (.60,.889,-.4938);
    HPUMP (1.0,0.0,0.0);        Refer to part of this appendix titled,
    .                           EQUIPMENT PERFORMANCE PARAMETERS-PUMPS.
    .
    .
END;
```

General

The program calculates boiler performance in two steps. First, the air/fuel ratio, heat content of the fuel, and the stack temperature (all **SPECIAL PARAMETERS**) are used along with the ambient temperature and humidity ratio to compute the theoretical full-load boiler efficiency and theoretical fuel required to meet the load. The following semi-empirical relationship is used to compute theoretical efficiency (efficiency is expressed as a fraction from 0 to 1):

$$\eta = \left[.87 - 1.25\left(\frac{\mathrm{SRATB}}{\mathrm{HFUELB}}\,[\mathrm{TLEAVE} - \mathrm{TAIR}] \cdot C_{p/ex}\right)\right] \qquad \text{[Eq G24]}$$

where:

- η = efficiency
- STRATB = air to fuel ratio in lb/lb
- HFUELB = heating value of fuel as fired in Btu/lb
- TLEAVE = boiler stack leaving temperature in °F
- TAIR = ambient air temperature °F (air is assumed to be dry)
- $C_{p,ex}$ = specific heat of exhaust (assumed constant at .24 Btu/lb · °F)

Using the default values for **STRATB, HFUELB,** and **TLEAVE** (all **SPECIAL PARAMETERS**), and assuming dry entering combustion air at 77°F, η = 0.749. The value of η depends on user-specified values for **STRATB, HFUELB,** and **TLEAVE**. Minor adjustments are also made during execution for the humidity ratio of incoming air.

The theoretical fuel consumption is modified to account for boiler heat losses to obtain actual fuel consumption, using the set called **RFUELB**. These parameters define the ratio of theoretical fuel consumption to actual fuel consumption as a function of boiler PLR. Thus,

$$\frac{\text{theoretical fuel consumption}}{\text{actual fuel consumption}} = A1 + A2 \cdot (PLR) + A3 \cdot (PLR)^2 \qquad \text{[Eq G25]}$$

where A1, A2, and A3 are the parameters of the **RFUELB** set, and PLR is the boiler part-load ratio. Note that boiler efficiency is not a function of part load, but rather the ratio of theoretical to actual efficiency is a function of part load when the **RFUELB** parameters are computed.

Example 1

First consider a high-pressure steam boiler whose stack temperature is 550°F (the default). Hypothetical part-load data at standard conditions (dry air and 77°F) might be:

Table G17
Hypothetical Part-Load Data

PLR	Actual Efficiency
1.1	.720
1.0	.730
.8	.725
.6	.716
.4	.700
.2	.650

The theoretical efficiency at these conditions is .749. Note that

$$\frac{\text{theoretical fuel consumption}}{\text{actual fuel consumption}} = \frac{\text{actual efficiency}}{\text{theoretical efficiency}} \qquad \text{[Eq G26]}$$

Table G18, necessary to calculate the RFUELB coefficients, can be generated. For .8 PLR, for example, the actual/theoretical is .725/.749 = .968.

Table G18
Data for Finding RFUELB Coefficients

actual efficiency / theoretical efficiency	PLR
.961	1.1
.975	1.0
.968	.8
.956	.6
.935	.4
.868	.2

After curve-fitting:

$$\frac{\text{actual efficiency}}{\text{theoretical efficiency}} = \frac{\text{theoretical fuel consumption}}{\text{actual fuel consumption}} = .801 + (.405)\text{PLR} + (-0.235)\text{PLR}^2$$

To simulate this boiler, the user must specify:

```
RFUELB (.8Ø1, .4Ø5, -Ø.235);
```

Example 2

This example is perhaps more typical of a low-temperature hot water boiler. In this case, the stack temperature is 300°F (the special parameter TLEAVE defaults to 550°F, so it must be changed) and the resulting theoretical efficiency is .813 for the same air/fuel ratio and fuel heating value as before. The actual full-load efficiency is .79, and the test data are:

Table G19
Boiler Part-Load Performance

PLR	FFLF Input (Fraction of Full-Load Fuel Input)
1.0	1.00
.8	.81
.6	.63
.4	.45
.2	.27

The actual efficiency at part load is computed from the data in Table G19 as follows:

$$\text{actual efficiency} = .79\left(\frac{\text{PLR}}{\text{FFLF Input}}\right)$$

Table G20 shows the ratio of actual efficiency-to-theoretical efficiency for various loads.

Table G20
Ratio of Actual Efficiency to Theoretical Efficiency for Part Loads

actual efficiency / theoretical efficiency	PLR
.972	1.0
.960	.8
.925	.6
.864	.4
.720	.2

After curve-fitting:

$$\frac{\text{actual efficiency}}{\text{theoretical efficiency}} = .563 + .921 \cdot (\text{PLR}) - 0.518 \cdot (\text{PLR})^2$$

For this boiler, the specification is

RFUELB (.563, .921, -Ø.518);

The curves in Figure G1 illustrate the default RFUELB curve as well as the RFUELB curve for the above examples.

Summary

The parameter sets for the examples will be specified by:

RFUELB (.8Ø1, .4Ø5, -.235);

or

RFUELB (.563, .921, -.518);

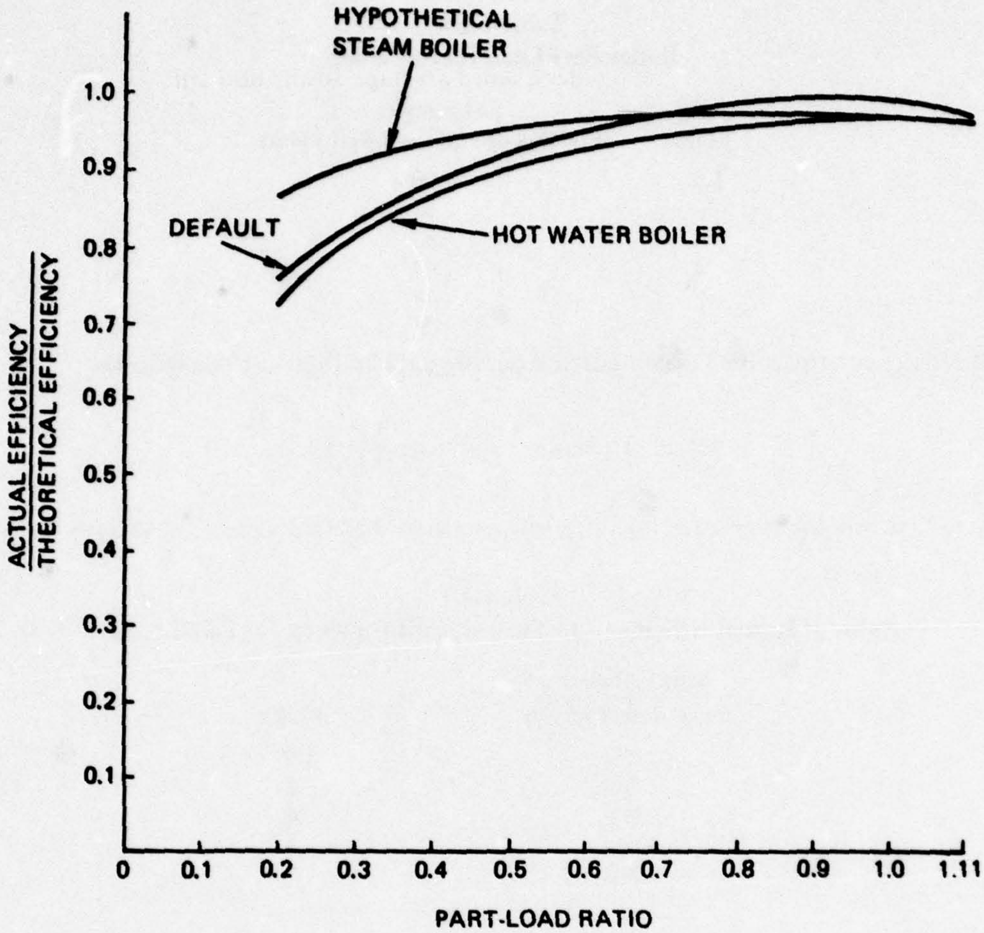

Figure G1. Actual theoretical efficiency vs PLR for boilers.

Equipment Performance Parameters - One-Stage Absorber, One-Stage Absorber (Solar Driven), Two-Stage Absorber, and Two-Stage Absorber with Economizers

Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS:
      .
      .
      .
      REN1A(.191,.91,.388);
            for one-stage absorption chiller
      REN2A(.11467,.67212,.21212);
            for two-stage absorption chiller
      REN2AE(.12917,.36902,.51136);
            for two-stage absorption chiller with economizer
      CAVL1A(1.0,-.016,0.0);
            for solar driven one-stage absorption chiller
      .
      .
      .
END;
```

General

Single-stage, two-stage absorption chillers, and two-stage absorption chillers with economizers are modeled using the equipment performance parameter sets **REN1A, REN2A,** and **REN2AE,** respectively. In each case, the heat power consumed by the absorber is:

$$\text{Heat Power} = \text{CL} \cdot \left(\frac{\text{A1}}{\text{PLR}} + \text{A2} + \text{A3} \cdot \text{PLR}\right) \qquad \text{[Eq G27]}$$

where: CL = chiller load
PLR = part-load ratio
A1, A2, and A3 = appropriate performance coefficients of the **REN1A, REN2A** or **REN2AE** sets.

Thus, the **REN1A, REN2A,** and **REN2AE** coefficient sets establish the ratio of heat power in-to-cooling effect produced as a function of part load. The ratio of heat power in-to-cooling effect produced is the *inverse* of the coefficient of performance.

To generate the coefficients, Eq 27 can be rearranged as follows:

$$[\text{Heat Power/CL}] \cdot \text{PLR} = \text{A1} + \text{A2} \cdot (\text{PLR}) + \text{A3} \cdot (\text{PLR})^2$$

For single-stage absorption chillers which are to be driven by solar collectors, the **CAVL1A** coefficient set is used to specify the maximum part-load ratio as a function of the difference between the full-capacity temperature (**TSATUR** from **SPECIAL PARAMETERS**) and the temperature of the solar tank.

$$\text{PLR}_{max} = \text{B1} + \text{B2} \cdot (\Delta T) + \text{B3} \cdot (\Delta T)^2 \qquad \text{[Eq G28]}$$

where: PLR_{max} = the maximum allowable PLR (a capacity limit)
ΔT = TSATUR − T_{tank}

Example

This example illustrates how manufacturer's data can be transformed to yield the appropriate **REN1A** coefficients.

According to the manufacturer of a single-stage absorber without economizer, the heat input at full load is 17800 Btu/hr-ton or 1.483 Btu/hr. This is the full load Heat Power/CL.

Table G21
Data from Manufacturer's Part-Load Curve

FFL	PLR
1.00	1.0
.90	.9
.79	.8
.68	.7
.59	.6
.42	.4
.26	.2
.18	.1

To convert the data for curve-fitting, the heat power per unit cooling load is 1.483 (FFL/PLR) for part load. Table G20 lists the results of [Heat Power/CL] · PLR = 1.483 · FFL.

Table G22
Inverse COP · PLR vs PLR

[Heat Power /CL] · PLR	PLR
1.483	1.0
1.335	.9
1.172	.8
1.008	.7
.875	.6
.623	.4
.386	.2
.287	.1

From a curve-fitting:

$$[\text{Heat Power/CL}] \cdot (\text{PLR}) = .191 + .910 \cdot (\text{PLR}) + .388 \cdot (\text{PLR})^2$$

The performance coefficients for this single-stage absorber can be specified by:

REN1A (.191,.910,.388);

Values for the **REN2A** and **REN2AE** sets of coefficients can be determined in the same way.

Example 2

This example illustrates how manufacturer's data can be transformed to yield the appropriate **CAVL1A** coefficients for a solar driven absorption chiller.

A manufacturer states that the maximum PLR of an absorber for solar application is .15 at 170°F and 1.0 at 240°F and that its change in PLR_{max} is roughly proportional to temperature. Thus, the *change* in PLR as a function of ΔT is:

$$\frac{1.0 - .15}{170 - 240} = -.0121$$

Thus:

$$PLR_{max} = 1 - 0.0121 \cdot (\Delta t)$$

The term B3 is zero, since for this absorber, a straight-line relationship exists.

The parameter for this example is:

CAVL1A (1, -.0121, 0);

Summary

A complete set of parameters for the example solar driven single-stage absorption chiller is:

REN1A (.191, .910, .388);
CAVL1A (.1184, -.0121, 0);

Equipment Performance Parameters - Double-Bundle Chiller, Heat Pump, and Chiller, Open Chiller, Reciprocating Chiller

Requisite Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS:
    .
    .
    .
    ADJTDB (95,1.19,44);
    RCAVDB (1.006,-.019,.00022);
    ADJEDB (3.158,-3.313,1.154);
    RPWRDB (.16017,.31644,.51894);
        for double-bundle chillers,

    ADJTHP(                 );
    RCAVHP( same as above );
    ADJEHP(                 );
    RPWRHP(                 );
        for heat pumps,
    ADJT1C(                 );
    RCAV1C( same as above );
    ADJE1C(                 );
    RPWR1C(.16017,.31644,.51894);
        for hermetic chillers,

    ADJT2C(                 );
    RCAV2C( same as above );
    ADJE2C(                 );
    RPWR2C(.239,-.04045,.79545);
        for open chillers

    ADJT3C(                 );
    RCAV3C( same as above );
    ADJE3C(                 );
    RPWR3C(.1494,.9568,-.11184);
        for reciprocating chillers,

    CPUMP(1.0,0.0,0.0);
    .
    .
    .
END;
```

Caution: special parameter RAVRHDB may have an unacceptable default value. Special parameter TCW must be adjusted to the temperature at which heat is recovered.

Caution: special parameter RAVRHHP may have an unacceptable default value. Special parameter TCW must be adjusted to the temperature at which heat is recovered.

Refer to part of this appendix titled, EQUIPMENT PERFORMANCE PARAMETERS–PUMPS.

Double-Bundle Chiller

General

All reciprocating and centrifugal chillers, heat pumps, and double-bundle chillers are modeled in the same way. Taking the double-bundle chiller as an example, first the chiller capacity is ad-

justed to reflect the change in condenser water temperature using the **RCAVDB** and **ADJTDB** equipment performance parameters. The **ADJTDB** coefficients are used to define an equivalent temperature difference between leaving chilled water and leaving condenser water. The first and last coefficients are the rating point temperatures for condenser water leaving and chilled water leaving, respectively. The second coefficient is the number of degrees that the temperature of the leaving chilled water rises or falls from the rating point to maintain the same rated capacity. The equivalent temperature difference is zero at the rated conditions. Next, the full-load power consumption is adjusted using the **ADJEDB** parameter set. Finally, the fraction of full-load power, FFL, is determined for part-load operation using the **RPWRDB** parameter set.

Example

The catalog showing capacity vs leaving condenser water and chilled water temperature lists the chiller to be simulated as having a capacity of 1073 tons (its nominal capacity) at 95°F and 44°F. Thus, the first and last coefficients of the **ADJTDB** set are 95 and 44, respectively. At 97.5°F and 46°F, the unit has a capacity of 1070 tons. A slight interpolation of the catalog data suggests that the unit has a capacity of 1073 tons (its nominal capacity) at 97.37°F and 46°F. The condenser water is 2.37°F higher than at the rating point, while the chilled water is 2°F higher. The second coefficient of the **ADJTDB** set is 2.37/2 or 1.19. Thus, the **ADJTDB** parameter set is:

ADJTDB (95,1.19,44);

The Figure G2 shows ΔT for various condenser water and leaving chilled water temperatures for the above **ADJTDB** coefficients.

The ratio of available capacity-to-nominal capacity is adjusted by using the equivalent temperature difference and the **RCAVDB** parameter set so that

$$\frac{\text{available capacity}}{\text{nominal capacity}} = B1 + B2 \cdot (\Delta T) + B3 \cdot (\Delta T) \qquad \text{[Eq G29]}$$

where: B1, B2, and B3 are the parameters of the **RCAVDB** set.

In this example:

$$\Delta T = [(T_{cond} - 95)/1.19] - [T_{cw} - 44]$$

where: T_{cw} is the actual temperature of the leaving chilled water
T_{cond} is the actual temperature of the leaving condenser water.

To find the **RCAVDB** coefficients for this example chiller, use the same manufacturer's table of available capacity vs condenser and chilled water temperature. Several values have been selected and listed in Table G23.

After curve-fitting:

$$\frac{\text{available capacity}}{\text{nominal capacity}} = 1.006 - 0.019 \cdot \Delta T + 0.00022 \cdot (\Delta T)^2$$

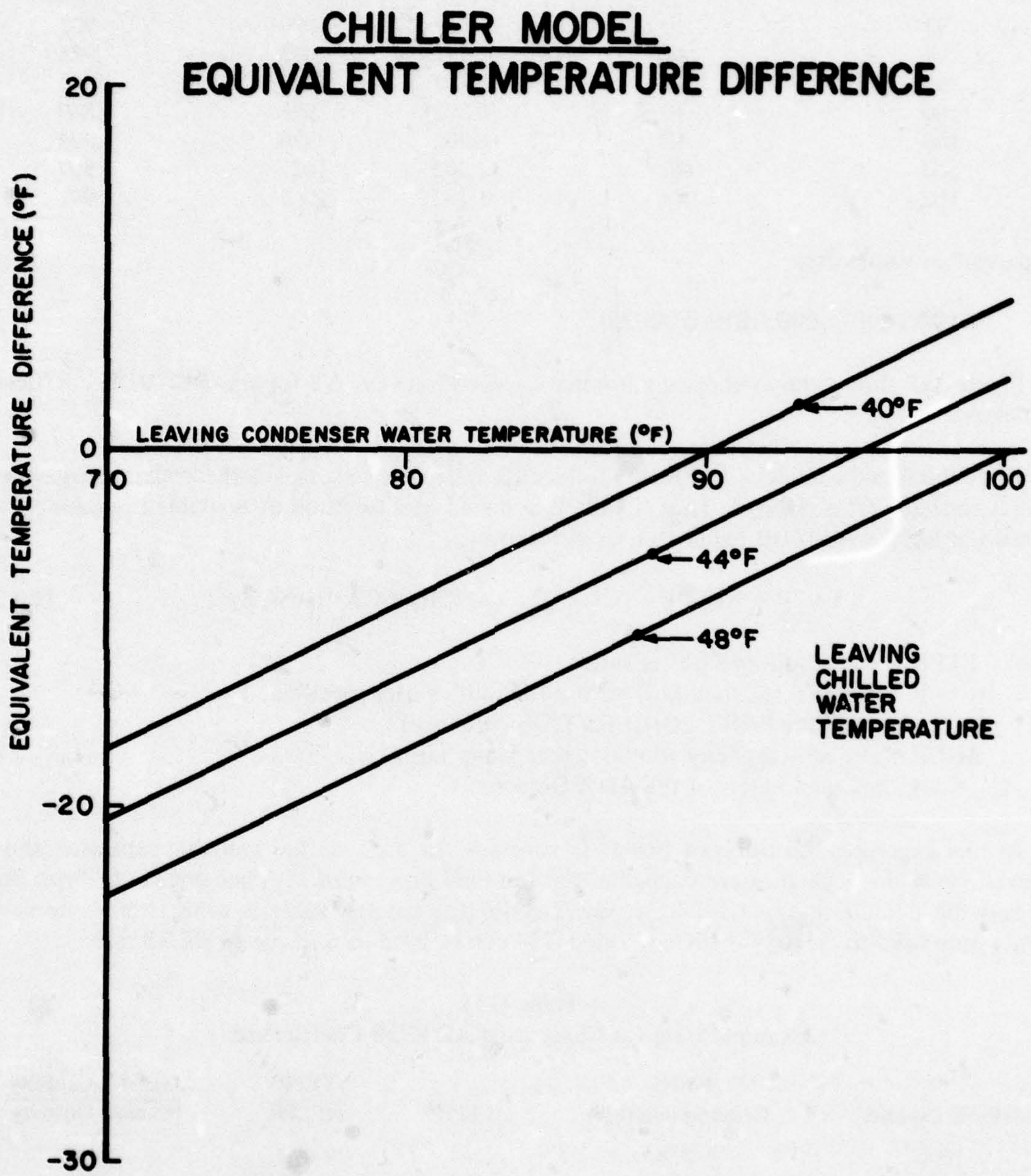

Figure G2. ΔT for various leaving condenser water and leaving chilled water temperatures for ADJTDB (95,1.19,44);.

Table G23
Data for Computing the RCAVDB Coefficients

Leaving Condenser Water Temperature	Leaving Chilled Water Temperature	ΔT	Available Capacity	Available Capacity / Nominal Capacity
95	40	+4	1000	.932
95	42	+2	1053	.981
95	46	−2	1127	1.050
100	40	+8.202	923	.860
100	42	+6.202	970	.904
100	46	+2.202	1027	.957
100	48	+.202	1063	.991

The parameter values are:

RCAVDB (1.ØØ6,-.Ø19,Ø.ØØØ22);

Figure G3 shows the available-to-nominal capacity ratio vs ΔT for the RCAVDB coefficients listed above.

In double-bundle chillers, FLPR, the full-load power ratio, changes as the available capacity-to-nominal capacity ratio changes. Thus, FLPR is adjusted as a function of available-to-nominal capacity ratio, using the ADJEDB parameter set as follows:

$$FLPR = NFLPR \cdot [C1 + C2 \cdot (ANCR) + C3 \cdot (ANCR)^2] \qquad \text{[Eq 30]}$$

where: FLPR = actual full-load power ratio
NFLPR = nominal full-load power ratio (default or user-specified, using the PART LOAD RATIOS sequence)
ANCR = available capacity to nominal capacity ratio
C1, C2, C3 are parameters of the ADJEDB set.

In this example, the full-load power is constant for each of the available capacities shown. However, since the capacities are changing, the full-load power *ratio* is changing. Data from Table G21 and the default nominal full-load power ratio (the catalog value is nearly the same as this default) were used to create Table G24. Table G24 can be used to find the ADJEDB set.

Table G24
Example Data for Computing ADJEDB Coefficients

Available Capacity	Power Consumption (kW)	FLPR*	FLPR / NFLPR	Available Capacity / Nominal Capacity
1000	858	.244	1.073	.932
1053	858	.232	1.019	.981
1127	858	.216	.952	1.050
923	858	.264	1.163	.860
970	858	.251	1.106	.904
1027	858	.238	1.045	.957
1063	858	.299	1.009	.991

*FLPR = (kW/ton) · .2843 (tons/kW).

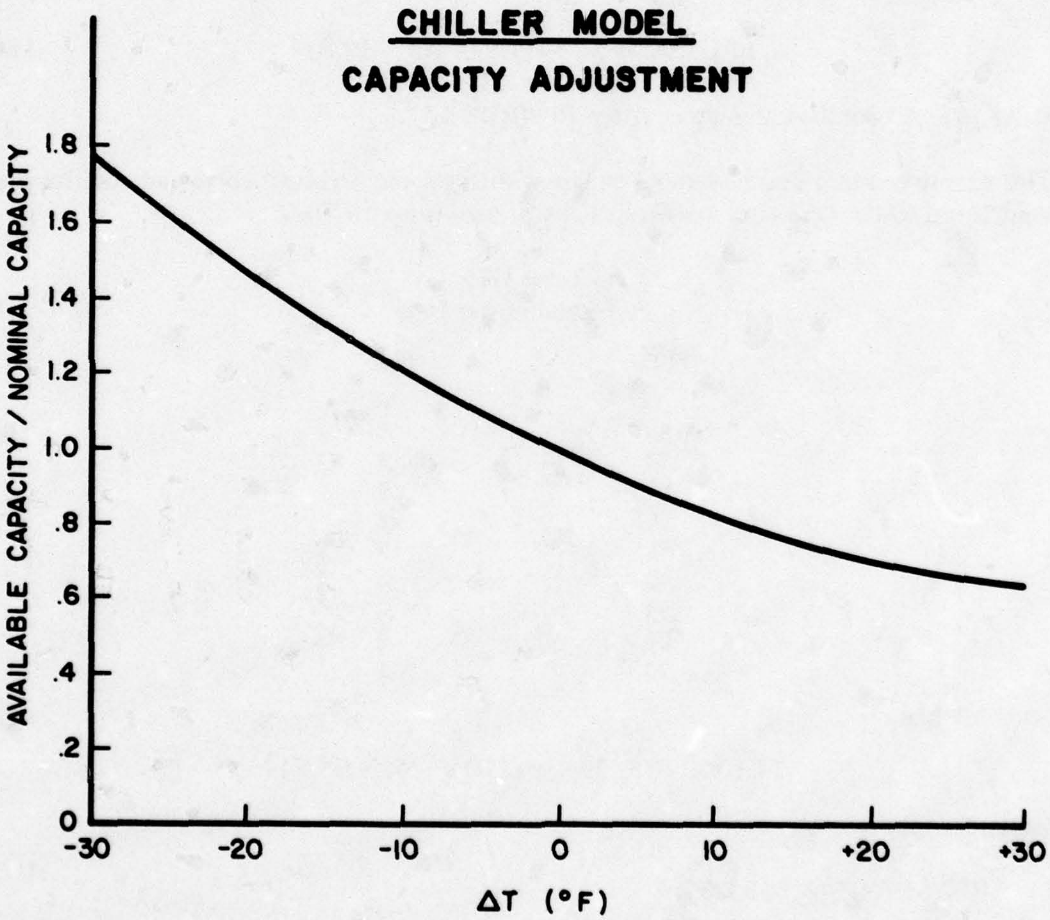

Figure G3. ΔT vs availability-to-nominal capacity ratio for RCAVDB (1.ØØ6,-.Ø19,Ø.ØØØ22);.

From curve-fitting:

$$\frac{FLPR}{NFLPR} = 3.158 - 3.313 \cdot (ANCR) + 1.154 \cdot (ANCR)^2$$

The parameter values are:

ADJEDB (3.158,-3.313,1.154);

Figure G4 shows actual-to-nominal FLPR vs available-to-nominal capacity ratio for the ADJEDB coefficients listed above.

The double-bundle chiller simulation must be able to calculate part-load performance. This is accomplished by computing FFL, the fraction of full-load power, as a function of PLR (PLR is the cooling load divided by the actual, not nominal, capacity) using the RPWRDB parameter set.

$$FFL = A1 + A2 \cdot (PLR) + A3 \cdot (PLR)^2 \qquad \text{[Eq 31]}$$

where: A1, A2, A3 are the parameters of the RPWRDB set.

This example uses a double-bundle chiller with the same part-load curve and coefficients used for a centrifugal chiller (the same centrifugal compressor is used). Thus:

Table G25
Part-Load Power Data

FFL	PLR
1.00	1.0
.89	.9
.78	.8
.68	.7
.59	.6
.51	.5
.42	.4
.34	.3
.27	.2
.20	.1

After curve-fitting:

$$FFL = .140 + .593 \cdot (PLR) + .265 \cdot (PLR)^2$$

The parameter values are:

RPWRDB (.140,.593,.265);

The Figure G5 shows the FFL as a function of the cooling load to actual capacity ratio for the RPWRDB coefficients listed above.

The final power demand calculation for double-bundle chillers has the same form as the equation for compression chillers:

$$Power = FLPR \cdot CAP \cdot FFL \qquad \text{[Eq 32]}$$

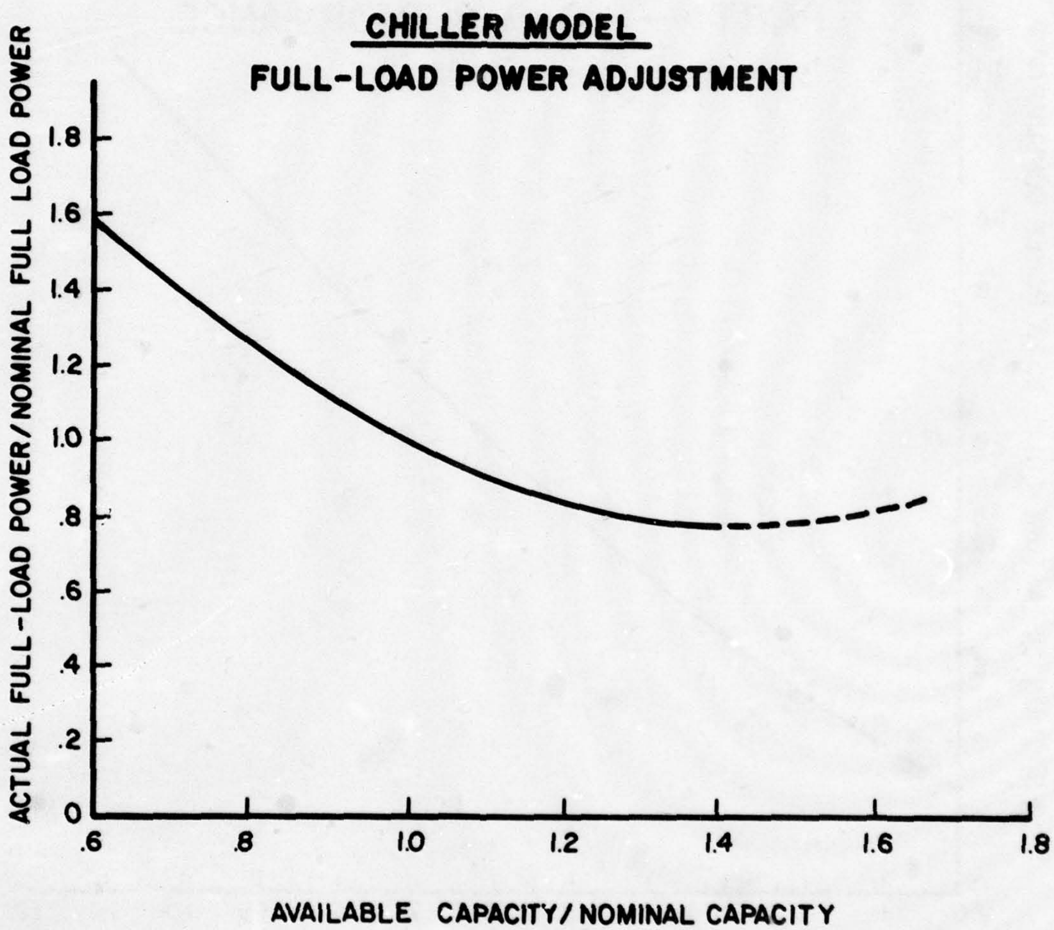

Figure G4. Actual-to-nominal FLPR vs available-to-nominal capacity ratio for ADJEDB (3.158,-3.313,1.154);.

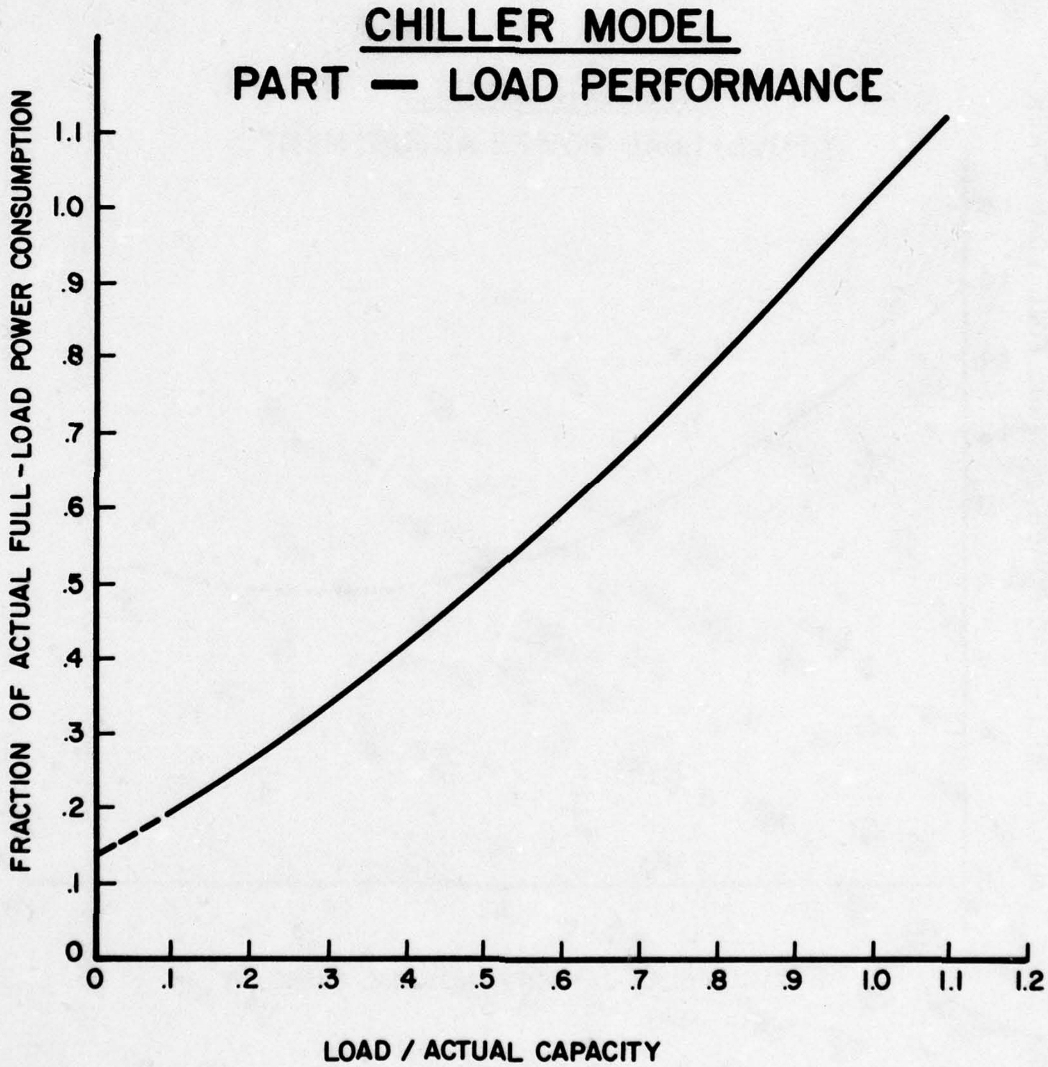

Figure G5. FFL as a function of the load-to-actual capacity ratio for RPWRDB (.14Ø,.593,.265);.

CAP is the adjusted available capacity based on the equivalent condenser water to chilled water temperature difference; FLPR is adjusted on the basis of the ratio of available to nominal capacity, and the FFL is adjusted on the basis of the ratio of the load to the *available* capacity (i.e., PLR = Cooling Load/Available Capacity).

Figure G6 shows the full- and part-load power consumption that would be calculated for various leaving condenser and chilled water temperatures using the above equipment performance parameters.

Summary

To change the performance parameters for double-bundle chillers, input:

```
EQUIPMENT PERFORMANCE PARAMETERS:
          .
          .
          ADJTDB (95,1.19,44);
          RCAVDB (1.ØØ6,-Ø.Ø19,.ØØØ22);
          ADJEDB (3.158,-3.313,1.154);
          RPWRDB (.14Ø,.593,.265);
          .
          .
END;
```

Heat Pump

The heat pump is simulated like the double-bundle chiller, except the heat pump can be false-loaded from the solar tank (if solar is used) to increase the rejected heat.

To change the performance parameter for heat pumps to match those derived in the example for double chillers, input:

```
EQUIPMENT PERFORMANCE PARAMETERS:
          .
          .
          .
          ADJTHP (95,1.19,44);
          RCAVHP (1.ØØ6,-Ø.Ø19,Ø.ØØØ22);
          ADJEHP (3.158,-3.313,1.154);
          RPWRHP (.14Ø,.593,.265);
          .
          .
          .
END;
```

Each parameter set is determined in the same way as the corresponding double-bundle parameter set.

Chiller, Open Chiller, Reciprocating Chiller

Chillers are simulated in the same way as double-bundle chiller simulation; however, no heat recovery is possible for chillers.

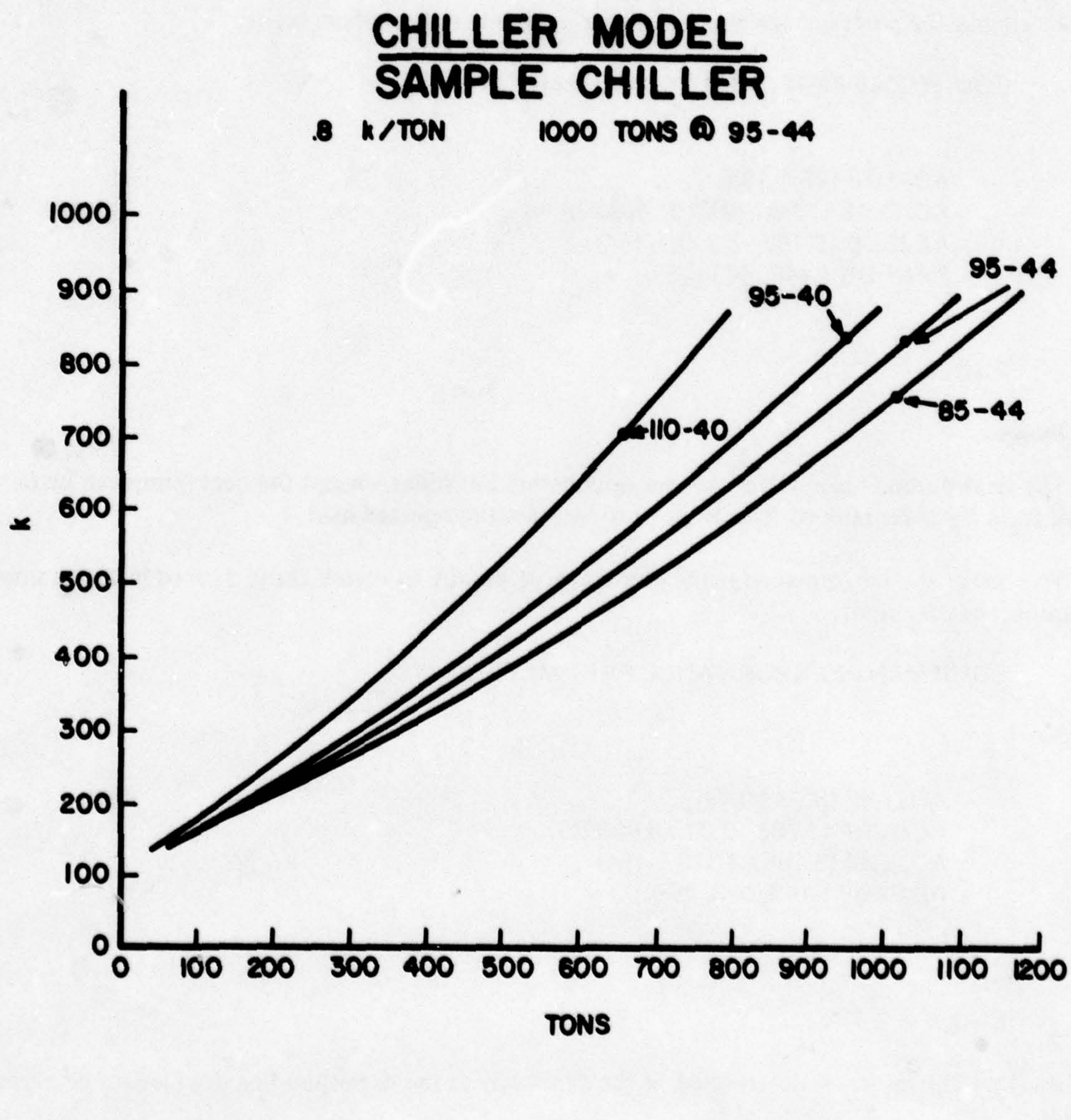

Figure G6. Full- and part-load power consumption calculated for various leaving and chilled water temperatures.

The performance parameters for chillers are:

```
EQUIPMENT PERFORMANCE PARAMETERS:
    .
    .
    .
    ADJT1C (95,1.19,44);
    RCAV1C (1.ØØ6,-Ø.Ø19,Ø.ØØØ22);
    ADJE1C (3.158,-3.313,1.154);
    RPWR1C (Ø.16Ø2,.3164,Ø.5189);
        for hermetric compression chillers (centrifugal),
    .
    .
    .
    ADJT2C (                          );
    RCAV2C (      same as above       );
    ADJE2C (                          );
    RPWR2C (.239,-.Ø4Ø4,.7954);
        for open centrifugal chillers,
    .
    .
    .
    ADJT3C (                          );
    RCAV3C (      same as above       );
    ADJE3C (                          );
    RPWR3C (.1494,.9568,-.1118);
        for reciprocating chillers,
    .
    .
    .
END EQUIPMENT PERFORMANCE PARAMETERS;
```

Each parameter set is determined in the same way as the corresponding double-bundle parameter set.

The variation of FFL vs PLR for each chiller type is shown in Figure G7.

Equipment Performance Parameters - Solar Collectors

Parameters and Default Values

```
EQUIPMENT PERFORMANCE PARAMETERS:
    .
    .
    .
    SOLAR (.813,-.ØØ2Ø574Ø,Ø.Ø);
    .
    .
    .
END;
```

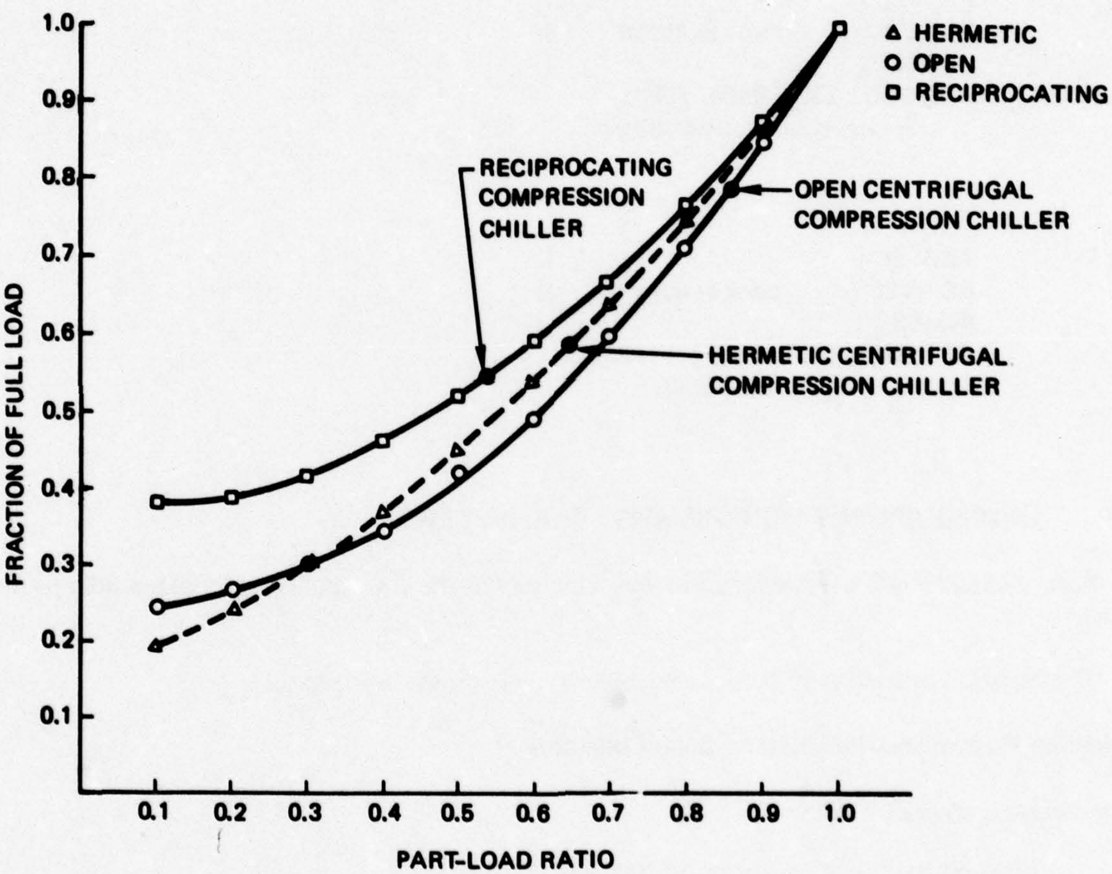

Figure G7. FFL vs PLR for compression chillers.

General

The amount of energy collected by solar collectors divided by the amount of incident solar radiation is a collector efficiency term. This term is a function of temperature, orientation, and solar intensity. BLAST computes collector efficiency, η, as a function of plate-to-ambient temperature difference divided by the normal insolation. This curve is the same as those generated by the National Bureau of Standards test procedure, except that the X-axis must be multiplied by 1000 to change from °F-hr-sq ft/Btu to °F-hr-sq ft/kBtu, which is the dimension that BLAST requires. The NBS procedure is given in J. E. Hill and T. Kusuda, *Method of Testing for Rating Solar Collectors Based on Thermal Performance*, Interim Report NBSIR 74-635 (National Bureau of Standards, December 1974). The collector efficiency equation is:

$$\eta = A1 + B1\alpha + B2\alpha^2 \quad \text{[Eq 33]}$$

where: η = collector efficiency

$$\alpha = \frac{\frac{T_{in} + T_{out}}{2} - T_{amb}}{Q_{inc}} \quad \text{[Eq G34]}$$

T_{in} = fluid temperature into the collector
T_{out} = fluid temperature out of the collector
T_{amb} = ambient air temperature
Q_{inc} = incident solar radiation on the collector

Example:

Table G26
Manufacturer's Data

η	α
.45	497
.56	363
.62	290
.68	216

After curve-fitting:

$$\eta = .8567 - .000817\alpha + 0.0\alpha^2$$

Summary

The complete solar collectors parameter set for the above example is:

```
.
.
SOLAR (.8567,-.000817,0.0);
.
.
```

Curves for this example and some typical collectors are given in Figure G8. The special parameters **TILT** and **AZMUTH** are used in modeling solar collectors, to calculate solar flux on the collector. Using Eq 33 and special parameters **HTXEFF**, **TNKCAP**, **FLOWRT**, and current demands for heat energy, a heat balance is performed (using the tank temperature from the previous hour as T_{in}) to determine the amount of energy collected and stored, used, or wasted. Two iterations are performed; on the first, $\alpha = T_{in} - T_{amb}/Q_{inc}$ and η and T_{out} are calculated based on the collector performance equation using this first estimated value for α; on the second iteration α is calculated using T_{out} calculated during the first iteration. **MXTNKT**, **TMINC**, **TMINH**, and **TMINHP** are all special parameters effecting solar energy system performance.

Equipment Performance Parameters — Pumps

Parameters and Default Values

CPUMP (1.Ø, Ø.Ø, Ø.Ø)
HPUMP (1.Ø, Ø.Ø, Ø.Ø)

also uses Special Parameters **PELCL** and **PELHT**.

General

Pumps for hot and chilled water are modeled in the central plant automatically if a heating and/or cooling load exists in the plant.

Chilled Water Pumps

The model for the chilled water pump is:

$$CELEC = CCAP \cdot PELCL \cdot (A1 + A2 \cdot CPLR + A3 \cdot CPLR^2) \qquad \text{[Eq 35]}$$

where: CELEC = chilled water pump electrical consumption for the current hour
CCAP = installed chiller capacity
PELCL = pump power demand per unit cooling capacity (see special parameter discussion)
CPLR = PLR which is CLOAD/total installed chiller capacity for the current hour
A1, A2, A3 are the coefficients of the **CPUMP** set.

Hot Water Pumps

The model for the hot water pump is:

$$HELEC = HCAP \cdot PELHT \cdot (A1 + A2 \cdot HPLR + A3 \cdot HPLR^2) \qquad \text{[Eq G36]}$$

where: HELEC = hot water pump electrical consumption for current hour
HCAP = installed boiler capacity
PELHT = pump power demand per unit of boiler capacity (see special parameter discussion)
HPLR = PLR which is HLOAD/total installed boiler capacity
A1, A2, A3 are coefficients of the **HPUMP** set.

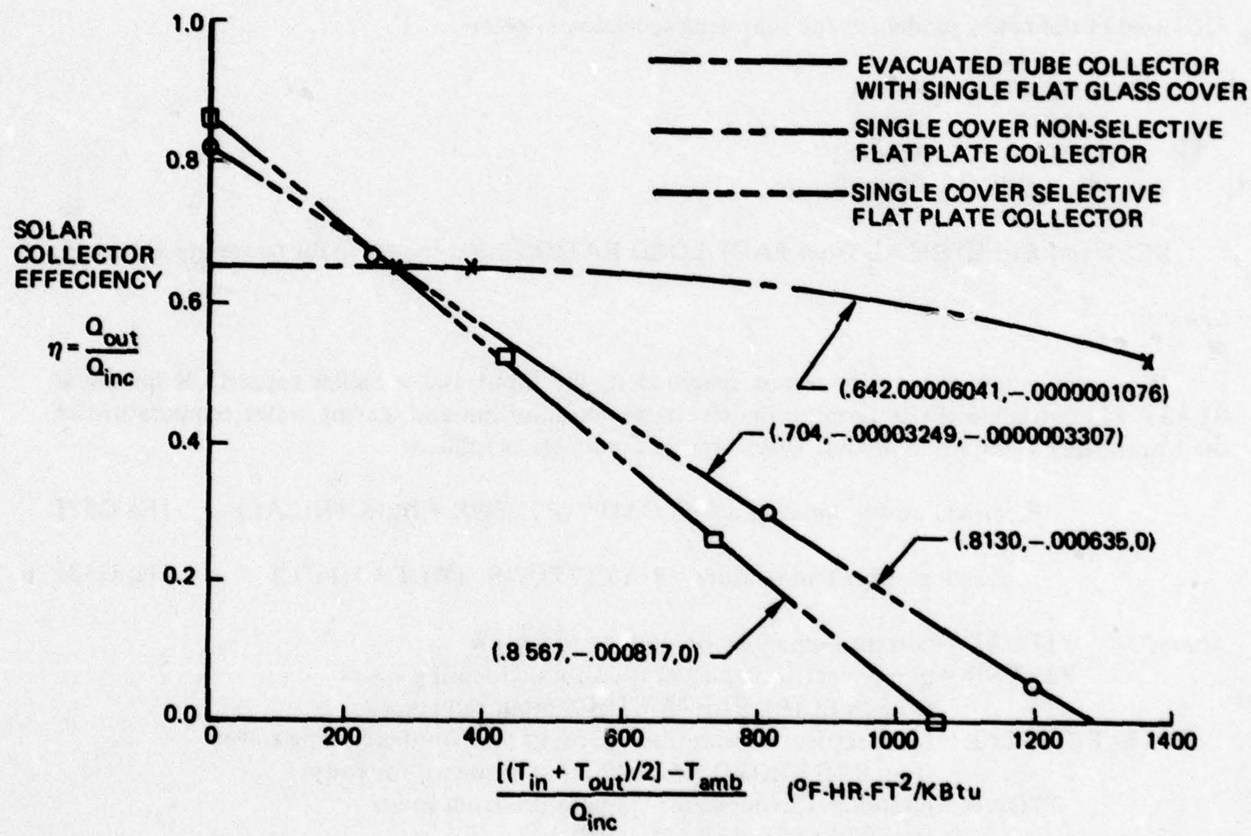

Figure G8. Solar collector performance curves.

Equipment Performance Parameters – Cooling Tower

Parameters and Default Values

```
.
.
.
RFR (0.0,.324,0.0);
RF1 (191.815,-2.183,.000594);
RF2 (230.5395,-2.688,.000749);
RF3 (126.2349,-1.452,.00040);
RF4 (131.58,-1.54,.000432);
RF5 (86.736,-1.0015,.00027685);
RF6 (70.128,-.80937,.00022401);
```

Also used in the tower model are the following special parameters:

TOWOPR	RWCA
TTOWR	TWCC
TCW	RWCDB
PELTWR	RWCHP

BEST and ELECTRICAL from PART-LOAD RATIOS input sequence for tower are also used.

General

If a cooling tower capacity is not specified in the input and a chiller capacity is specified, BLAST will automatically determine the electrical consumption and leaving water temperature of the tower using a simplified model. This simplified model is as follows:

$$\text{Electrical power consumed} = \text{TLOAD} * (\text{PELTWR} + \text{ELECTRICAL}) \qquad \text{[Eq G37]}$$

$$\text{Leaving water temperature} = \text{MAX}(\text{TTOWR}, \text{TWET} + 1.11°\text{C}) \qquad \text{[Eq G38]}$$

where: TLOAD = current hours load on cooling tower kW
PELTWR = pump electrical consumption for condensing water from SPECIAL PARAMETERS input sequence
ELECTRICAL = fan electrical consumption per unit load on the cooling tower from PART LOAD RATIOS input sequence for tower
TTOWR = minimum leaving water temperature from tower from SPECIAL PARAMETERS
TWET = current hour wet bulb temperature.

When a tower is specified, tower pump power is:

$$\text{Tower pump power} = \text{TCAP} \cdot \text{PELTWR}(\text{A1} + \text{A2} \cdot \text{HPLR}) + \text{A3} \cdot \text{HPLR}^2 \qquad \text{[Eq 39]}$$

where: TCAP = tower capacity
A1, A2, A3 = coefficients of the TPUMP set

HPLR = TLOAD/TCAP

In this version of BLAST, if a tower(s) is selected,

$$\text{Electric power} = \text{TLOAD} \cdot \text{ELECTRICAL} + \text{tower pump power} \qquad \text{[Eq 40]}$$

For information regarding the use of RFR and RF1-RF6 coefficients with BLAST, the user should contact his/her computer service company.

APPENDIX H: LIFE-CYCLE COSTING METHOD

The life-cycle costing method used in BLAST is the conventional present worth (present value) technique which includes both interest and inflation on all future costs.

The present worth of annually recurring costs is determined using the following formula:

$$PV = a \cdot F \left[\left(\frac{1+I}{1+i}\right)^{p} + \left(\frac{1+I}{1+i}\right)^{1+p} + \ldots + \left(\frac{1+I}{1+i}\right)^{n-1+p} \right] \quad \text{[Eq H1]}$$

where: PV = present value
F = first-year cost of recurring cost item
I = inflation rate
i = interest (or discount) rate
(INTEREST RATE from the LIFE CYCLE COST PARAMETERS)
n = project life in years (LIFE from LIFE CYCLE COST PARAMETERS)
p = PAYMENT TIME (from LIFE CYCLE COST PARAMETERS)
a = ADJUSTMENT FACTOR (from LIFE CYCLE COST PARAMETERS).

For recurring labor costs (routine maintenance, etc.), I takes on the value of LABOR INFLATION. For fuel cost, I takes on the value of INFLATION specified for each fuel type. For supply and equipment replacement cost, I takes on the value of SUPPLIES INFLATION.

The present worth of periodic replacement and/or overhaul costs is computed using the following formula:

$$PV = a \cdot F \left[\left(\frac{1+I}{1+i}\right)^{q_1-1+p} + \left(\frac{1+I}{1+i}\right)^{q_2-1+p} + \ldots + \left(\frac{1+I}{1+i}\right)^{q_j-1+p} + \ldots + \left(\frac{1+I}{1+i}\right)^{q_{last}-1+p} \cdot \left(\frac{n-q_{last}}{s}\right) \right] \quad \text{[Eq H2]}$$

where: PV = present value
F = replacement or overhaul cost at current prices
I = inflation rate (SUPPLIES INFLATION)
i = interest (or discount) rate
n = project life in years
p = PAYMENT TIME (from LIFE CYCLE COST PARAMETERS)
a = ADJUSTMENT FACTOR (from LIFE CYCLE COST PARAMETERS)
q_j = integral year in which the jth overhaul or replacement occurs, $q_j < q_{last}$
q_{last} = last q_j, occurring before n.
s = actual non-integer time between overhauls or replacements, in years.

Present value is reported for each type of cost for each year of the project life. The adjustment factor (a) is usually used to adjust periodic and recurring cost to account for the time between the midpoint of construction and the actual commencement of periodic and recurring costs. Major and minor overhauls, which fall into the same integer year as a replacement, are not included. Notice that last periodic cost is prorated according to the remaining life of the building or equipment.

APPENDIX I: ERROR MESSAGES FOR VOLUME I*

PARSER ERRORS

Errors in the PARSER generally are shown immediately after the line in which they occurred. Since the BLAST input may put more than one statement on a line, it may not always be clear exactly what the PARSER is referring to. The following messages should point to an area for the user to look for the actual error in the BLAST Users Manual.

Syntactical errors

Errors in user syntax appear as a group of messages; First, the PARSER shows what it thought was incorrect; Second, it shows what the attempted fix will be; Third, if the syntax cannot be made, "correct" will show how many statements are ignored as it tries to recover.

First Group possibilities:

```
                        $
** SEVERE ILLEGAL INPUT SYMBOL
        SYMBOL TYPE ENCOUNTERED WAS . . . <Type Encountered>
```

The $ will be beneath the column where the error occurred. <Type Encountered> will either be the word in error of if a special symbol, the kind of symbol in error. E.g. "-" is type MIOP, ";" is type SEMI.

Second Group possibilities:

A SYMBOL OF THE FOLLOWING TYPE WAS INSERTED . . . <Type inserted>

SYMBOL WAS DELETED, NEXT SYMBOL TYPE IS . . . <Next Type>

SYMBOL WAS REPLACED BY A SYMBOL OF TYPE. . . <Replacement Type>

UNSUCCESSFUL REPAIR, SYMBOL REPLACED BY SYMBOL OF TYPE. . . <Type> IF NEXT CORRECTION UNSUCCESSFUL, WILL GO TO NEXT BEGIN

Type is as described above under the First group.

Third Group:

```
** SEVERE UNABLE TO RECOVER LOCALLY
          FIND AN END OR BEGIN AND TRY AGAIN

** SEVERE UNRECOGNIZED WORD FOLLOWING BEGIN, SEARCHING FOR NEXT BEGIN
```

Cards between the original error and an END or BEGIN are displayed with "--- FLUSHED" shown to indicate that these cards will be ignored.

```
************************* STARTING WITH NEW BEGIN *************************
```

The PARSER will continue input starting with this BEGIN.

**In this appendix, the male pronoun is used to refer to both genders.*

PARSER Interpretation Errors

After accepting the syntax of the statement, the PARSER must interpret the statement and relay this information to the BLAST input data structure. Errors may occur at this time if the user has not input the proper elements of the statement (e.g. trying to retreive a wall from the library that does not exist; misspelling a key phrase; putting an improper range in the input).

Run Control and Library Change Errors

Severe Errors

DAYS NAMES MAY NOT BE USED AS PROFILE IDS

In a SCHEDULE definition, the user attempted to use a day name (MONDAY, TUESDAY, etc.) as a PROFILE identifier. This is not allowed.

HOLIDAY MAY NOT BE USED IN A DAY RANGE

In a SCHEDULE definition, the day range may not appear: SUNDAY THRU HOLIDAY.

HOUR IS ILLEGAL

In a hourly specification, the user attempted to input an hour outside the range of 0 to 24.

ILLEGAL DAY ELEMENT

In a SCHEDULE definition, the user attempted to input an illegal day. Only (MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY, SATURDAY, SUNDAY, and HOLIDAY) are allowable day elements.

ILLEGAL DEFINE–DELETE WITH FIELD

The user attempted to DELETE a library element, but input a definition field at the same time. This is illegal.

ILLEGAL DEFINE–NO DEFINITION THIS NAME

The user attempted to DEFINE a library element without inputting the rest of the proper define. The Users Manual should be checked for proper syntax.

ILLEGAL DEFINE–NO FIELD

The user attempted to DEFINE a library element, but did not input the definition field. This is illegal.

ILLEGAL DELETE–DEFINITION WITH FIELD

The user attempted to DELETE a library element, but input the information for a DEFINE. The Users Manual should be checked for proper syntax.

ILLEGAL DELETE–NAME = FIELD

The user attempted to DELETE a library element by inputting too much information. The Users Manual should be checked for proper syntax.

ILLEGAL DESIGN DAY ELEMENT

The user has input an invalid key in the definition of a DESIGN DAY. The Users Manual should be checked for proper syntax.

SCHEDULE EQUATED TO UNDEFINED SCHEDULE

The user attempted to DEFINE a schedule by equating it to a day that was not defined. e.g. SUNDAY=SATURDAY; and SATURDAY's schedule was not defined.

ILLEGAL LIBTYPE

The user has input an illegal library type (e.g., possibly misspelled MATERIALS, DESIGN DAY, etc). The Users Manual should be checked for proper library types.

ILLEGAL LIBTYPE FOR PARAMETER LIST

The user has input the wrong libtype for the syntax of the statement. The Users Manual should be checked for proper syntax.

ILLEGAL LOCATION DEF ELEMENT

The user has input an invalid key in the definition of a LOCATION. The Users Manual should be checked for proper syntax.

ILLEGAL MATERIAL ELEMENT

The user has input an invalid key in the definition of MATERIAL. The Users Manual should be checked for proper syntax.

ILLEGAL RUN CONTROL ELEMENT

The user has input something that is invalid to the RUN CONTROL section. The Users Manual should be checked for proper syntax.

ILLEGAL SCHEDULE ELEMENT

The user has input an invalid schedule element (possibly misspelled a day). The Users Manual should be checked for proper syntax.

INFORMATION FIELD OUT OF RANGE

INSUFFICIENT LOCATION DATA

The user has not provided enough information to define a LOCATION. The Users Manual should be checked for proper syntax.

LIBRARY ENTRY ALREADY EXISTS

LIBRARY ENTRY NOT FOUND

MATCHING TOO MANY DAYS

In a SCHEDULE definition, the day range was illegal. e.g. SUNDAY THRU SUNDAY = is not allowed.

NAME LENGTH OUT OF RANGE

OLD LIBRARY ENTRY NOT FOUND, MAKING NEW ENTRY

ONLY REPORTS MAY HAVE INTEGER FIELDS

The user attempted to input a RUN CONTROL element of the form: KEY (. . .) with integer fields between the parentheses. Only the REPORTS statement may use this option.

PROFILE ID NOT FOUND

In a CONTROLS definition, a profile was referenced by a SCHEDULE element, but had not been defined.

SURFACE CANNOT CONTAIN MORE THAN 10 CONSTRUCTION LAYERS

The user attempted to define a surface (WALL, FLOOR, etc) with more than 10 layers. This is illegal.

TAPE7 AND TAPE47 BOTH CONTAIN LIBRARIES

TEMPORARY LIBRARY ENTRY ALREADY EXISTS

TOO MANY GROUND TEMPERATURES

The user has input more than 12 temperatures in a GROUND TEMPERATURES = statement. Only 12 are allowed.

TOO MANY PROFILE ELEMENTS

In a SCHEDULE definition, the user attempted to input more than 8 elements of a profile ramp. A maximum of 8 are allowed.

TOO MANY PROFILES

In a SCHEDULE definition, the user attempted to input more than 10 profiles. Only 10 are allowed.

TOTAL NUMBER OF ENVIRONMENTS CANNOT EXCEED 13

The combined number of environments requested by the user cannot exceed 13. (Combined is the number of DESIGN DAYS plus the WEATHER TAPE, if requested).

UNRECOGNIZED LIBRARY TYPE

Warning messages

INVALID DESIGN DAY DATE—ASSUMING 21 JUL

The user has specified an invalid date when defining a DESIGN DAY. The date will be kept as 21 JUL.

LESS THAN 24 SCHEDULE ELEMENTS DEFINED

In a SCHEDULE definition, the user specified less than 24 hours in the hourly range.

NO LOCATION GIVEN

The user did not specify a LOCATION = during the run.

PROJECT TITLE LIMITED TO 320 CHARACTERS

The PROJECT = statement can specify a maximum of 320 characters for the project title. The first 320 characters will be retained.

Miscellaneous Errors That Can Occur in Each Block

Severe Errors

ATTEMPTED SCHEDULE OVERLAP

The user is inputting a schedule and overlapped the hours.

KEY NAME NOT FOUND

The user specified a "key name" that does not exist in the parser vocabulary. This error will usually precede a further definition of the error.

KEY NAME TOO LONG

The user has input a too long key name (>30 characters).

NAME LENGTH EXCEEDS MAX ALLOWABLE

The user has input a name that is too long. The Users Manual should be checked (in the proper section) for limitations.

WHAT IS THIS–SCANNER IGNORES

The user has input an illegal character.

UNRECOGNIZED MONTH

The user has input an invalid month specification. BLAST uses the first 3 characters of each month name as the valid month specifications.

Warning Errors

INTEGER EXPECTED, DECIMAL POINT FOUND ASSUMING--integer

The user input a real number where an integer was expected. The displayed integer is assumed.

LESS THAN 24 SCHEDULE ELEMENTS DEFINED

The user input a schedule with less than 24 hours. The remaining hours are defaulted to zero.

Fatal Parser Errors

With few exceptions the FATAL errors caused by the parser are not under user control and a BLAST consultant must be called. Fatal errors caused by user:

END OF INPUT IN MIDDLE OF STRING

The user probably forgot the ending " on a string.

STRING > 400 CHARACTERS, TOO LONG

The user probably forgot the ending " on a string. Maximum string length for any string in BLAST cannot exceed 400 characters.

Fatal errors not under user control are:

ERROR STATE STACK OVERFLOW

MARK MISSING FROM STACK

MARK STACK OVERFLOW

OVERFLOW OF LEXICAL STACKS

OVERFLOW OF SYMBOL TABLE

STATE STACK OVERFLOW

SYMBOL STACK OVERFLOW

Building Description Errors

Severe Errors

ILLEGAL ARGUMENT

The user has input a statement of type "key = (a at b, c at d)" but has misspelled or improperly used the "key".

ILLEGAL FEATURE–MUST BE WINDOWS OR DOORS

The user has input a statement "OF TYPE . . ." but the word following "TYPE" is not recognizable as "WINDOWS" or "DOORS",

ILLEGAL QUALIFIER

The user has "qualified" a statement with a qualifier of the wrong type. Qualifiers include "AT ACTIVITY LEVEL", "PERCENT RADIANT", "PERCENT LOST", etc. Typically this error means the user has applied a qualifier improperly; e.g. "PEOPLE = 300, PEO SCHED, 2 PERCENT RETURN AIR" is an error because the qualifier "PERCENT RETURN AIR" does not apply to PEOPLE.

ILLEGAL SUBSURFACE TYPE

The user has misspelled or illegally input a subsurface type. E.g. valid subsurface types include "WING", "WINDOW", etc.

ILLEGAL SURFACE TYPE

The user has misspelled or illegally input a surface type. E.g. valid surface types include "FLOOR", "CEILING UNDER ATTIC".

INVALID CONSTRUCTION

The user has input a construction (WALL, FLOOR, etc.) that does not exist on the user library.

MAXIMUM ZONE SURFACES EXCEEDED

The user has exceeded the number of zone surfaces allowed (100).

MAY NOT USE ACTIVITY LEVEL HERE

The user has specified the "AT ACTIVITY LEVEL" clause improperly. E.g. "LIGHTS=300,LIT SCHED, AT ACTIVITY LEVEL 2" is an error because the phrase "AT ACTIVITY LEVEL" does not apply to LIGHTS.

NO SURFACES OF TYPE TO BE DELETED WERE FOUND

The user has directed BLAST to delete surfaces in a new zone that is described with a "SAME AS" clause. The surfaces to be deleted were not found in the original zone.

SURFACE LIMIT EXCEEDED

The user has input more than the number of surfaces allowed for a single zone (Limit = 100).

SYMBOL NOT RECOGNIZED

The user has input a symbol (e.g. HEIGHT1) which he did not previously define.

TOO MANY COEFFICIENTS

The user has input more than 10 coefficients in a "WITH COEFFICIENTS" clause.

TOO MANY LEVEL OF NESTING NO MORE SPACE

The user has nested too many blocks. This error could result from too many "BEGIN BUILDING DESCRIPTION" blocks. The limit is 10.

TOO MANY SYMBOLS. NO MORE SPACE

The user has tried to define too many local identifiers in his zone. These symbols might include "HEIGHT1", "WIDTH1", etc. This limit is 150.

TOO MANY TOTAL GLASS LAYERS (CNSTRN)

The user has retrieved too many glass layers in describing the constructions for the building. Each "GLASS" material in a WINDOW construction counts as a glass layer. (Limit = 30 layers).

TOO MANY TOTAL MATERIALS (CNSTRN)

The user has input constructions such that the total number of materials has been exceeded. Each unique construction (WALL, DOOR, FLOOR, etc.) describes some number of material layers. (Limit = 100 materials).

TOO MANY UNIQUE SURFACE CONSTRUCTIONS (CNSTRN)

The user has input too many surfaces for the building. These type of constructions include unique WALLS, FLOORS, WINDOWS, etc. (Limit = 20 constructions).

'user input' ALREADY DEFINED

The user has attempted to define a symbol (e.g. HEIGHT1) more than once for a single run.

WITH ELEMENT TILT NOT ACTIVATED

The user has input a subsurface with a TILT clause. This is not allowed.

Warning Errors

BUILDING TITLE LIMITED TO 40 CHARACTERS

The user has input a building title of greater than 40 characters. Only the first 40 characters of user input will be retained.

NO SUBSURFACE POSITION GIVEN, (0,0) ASSUMED

The user has input a subsurface without specifying*****.

NO SUBSURFACE POSITION GIVEN ASSUMING AND POSITION AS FIRST

The user input a subsurface without specifying a starting position; the last and position is assumed.

ONLY ONE REVEAL PER WITH ALLOWED, USING FIRST

The user has input more than one reveal on a "WITH" statement. Only the first "REVEAL" will be used.

REVEAL MEANINGLESS ON WINGS OR OVERHANGS, IGNORING

The user input a "REVEAL" clause on a WING or OVERHANG subsurface. This reveal is ignored.

SUBSURFACE LOCATION GIVEN, ASSUMING / AND /

The user input a starting location for (presumably) a subsurface without specifying an "AND".

Fan System Description Errors

Severe Errors

INVALID COIL TYPE

The user has input a statement of type "COIL TYPE" = "key name", of which "key name" is invalid. Only "CHILLED WATER" and "DIRECT EXPANSION" are allowed.

INVALID ID IN SYSTEM PARAMETERS

The user has input a statement of type "id" (number, number, number) and "id" was invalid. The user manual should be checked for valid ids.

INVALID OR UNRECOGNIZED KEYWORDS

The user has input a statement of type "key name" = (various right hand side of which the "key name" is not allowed for this type of statement).

INVALID OR UNRECOGNIZED PARAMETER KEY WORDS

The user has input a statement of type "key name" = "key name", of which the second "key name" is not recognizable as valid for the first "key name".

INVALID PARAMETER OR SCHEDULE HEADER

The user has input a PARAMETERS or SCHEDULES header in which he probably misspelled the name of the parameters or schedules he desired. The Users Manual should be checked for proper names.

INVALID PHRASE, SHOULD BE POWER COEFFICIENTS

The user input a statement "FAN phrase" = (numbers) and the phrase was not "POWER CO–EFFICIENTS".

INVALID SYNTAX, INVALID PHRASE FOR THIS SECTION

The user has input a statement of type "key name" = number, of which "key name" is not valid for the current section (PARAMETERS or ZONE).

INVALID SYNTAX, NUMBER INVALID FOR THIS PHRASE

The user has input a statement of type "key name" = number, of which "key name" is not validly used with a number.

INVALID ZONE NUMBER FOR HUMIDISTAT

The user has input a statement of type "HUMIDISTAT LOCATION" = number and number is not a valid zone number for this system. i.e. the number did not appear in the "SERVING ZONES" clause.

MAXIMUM NUMBER OF ZONES EXCEEDED

The user has input too many zones (>20) in the "SERVING ZONES" clause.

ONLY A NUMBER OR DESIRED MIXED AIR TEMPERATURE IS ALLOWED HERE

The user has input a statement of type "PREHEAT TEMPERATURE" = "key name" and "key name" is not DESIRED MIXED AIR TEMPERATURE.

ONLY COLD DECK TEMPERATURE OR A NUMBER IS VALID HERE

The user has input a statement "DESIRED MIXED AIR TEMPERATURE" = "key name" and "key name" is not COLD DECK TEMPERATURE.

ONLY CONTINUOUS OR INTERMITTENT IS ALLOWED HERE

The user has input a statement of type "SYSTEM OPERATION" = "key name" and "key name" is not CONTINUOUS or INTERMITTENT.

SUPPLY AIR VOLUME MUST BE SPECIFIED

The user has input a SYSTEM block without specifying a SUPPLY AIR VOLUME for each zone in the SERVING ZONES clause.

VALID ONLY INSIDE OF A ZONE

The user has input a statement of type "key name" = "key name", of which the first "key name" is only allowed inside a "for zone:" clause.

WRONG NUMBER OF PARAMETERS

The user has input the statement "FAN POWER COEFFICIENTS" = (numbers) and there were not 5 numbers within the parentheses.

ZONE NUMBER DOES NOT APPEAR IN SERVING CLAUSE

The user has input a statement "FOR ZONE number" and number is not in the SERVING ZONES clause.

Warning Errors

COLD DECK TEMPERATURE IGNORED

The user has input "COLD DECK TEMPERATURE" = number and had already input "COLD DECK CONTROL" = "ZONE CONTROLLED" or "COLD DECK CONTROL" = "OUTSIDE AIR CONTROLLED". This COLD DECK TEMPERATURE will be ignored.

DUPLICATE ZONE NUMBER IN LIST: number–DUPLICATE DELETED

The user has specified a duplicate number in his SERVING ZONES clause. This number is ignored.

HOT DECK TEMPERATURE IGNORED

The user has input "HOT DECK TEMPERATURE" = number and had already input "HOT DECK CONTROL" = "ZONE CONTROLLED" or "HOT DECK CONTROL" = "OUTSIDE AIR CONTROLLED". This HOT DECK TEMPERATURE will be ignored.

SYSTEM TITLE LIMITED TO 40 CHARACTERS

The user has input a system title (SYSTEM number "title") of greater than 40 characters. Only the first 40 characters will be retained.

Central Plant Errors

Severe Errors

EQUIPMENT TYPE/SIZE not SELECTED

The user has referenced a size of an equipment type that has not previously been input.

INVALID BLOCK SPECIFICATION

The user has probably misspelled "BLOCK" in his input.

INVALID COST TYPE

The user has input an invalid COST TYPE in specifying a COST parameter. The Users Manual should be checked for valid types.

INVALID EQUIPMENT TYPE–name

The user has input an invalid equipment name in a name (number, number, number) type of statement. The invalid name is shown. The Users Manual should be checked for valid names.

INVALID EQUIPMENT TYPE

The user has input an equipment type that isn't valid. The Users Manual should be checked for proper equipment types.

INVALID HOT WATER SCHEDULE TYPE

The valid types for a HOT WATER SCHEDULE are WEEKDAY HOT WATER or WEEKEND HOT WATER.

INVALID LIFE CYCLE COST PARAMETERS

The user has specified an invalid name in inputting the LIFE CYCLE COST block. The Users Manual should be checked for valid names.

INVALID OTHER COST PARAMETERS

The user has input invalid parameters in an "OTHER COST" block. The Users Manual should be checked for valid parameters.

INVALID PARAMETER TYPE–> name

The user has input an invalid name in a ("p. type"=number, "p. type"=number) statement. The four allowable parameter types are MIN, MAX, BEST, ELECTRICAL.

INVALID PARAMETER TYPE–> user input

The user has specified an invalid parameter in a "SPECIAL PARAMETERS" list (invalid input is shown). The Users Manual should be checked for valid parameters.

NO SYSTEMS ON AHLDFL

The user has requested "ALL SYSTEMS" in his SERVING clause and no systems appear on the AHLDFL.

SYSTEM NUMBER NOT FOUND

The user has input a system number in a "FOR SYSTEM number:" clause and the number does not appear in his "SERVING SYSTEMS" clause (or not on the AHLDFL if user input "SERVING ALL SYSTEMS").

TOO MANY BLOCKS

The user has input too many (>10) BLOCK specifications.

TOO MANY SYSTEMS

The user has requested too many (>60) systems in his SERVING SYSTEMS clause.

Warning Errors

DUPLICATE SYSTEM NUMBER IN LIST: number–DUPLICATE DELETED

The user has input a duplicate system number in his SERVING SYSTEMS clause. The displayed number will be ignored.

IGNORING: ALL–

If the user inputs "SERVING ALL SYSTEMS number, number, etc." the ALL specification is ignored and only the specified numbers are used.

PLANT TITLE MUST BE 320 CHARACTERS OR LESS

The user has input a plant title (PLANT number "title") of greater than 320 characters. Only the first 320 characters will be retained.

Errors Caused Indirectly

These errors typically indicate that the user has input too much for BLAST to handle and the user must reduce his/her input specifications. The user may also have too many errors for BLAST to continue to process his/her deck. In this case, the user should attempt as many fixes to his/her input as possible and rerun.

ERROR MARK STACK OVERFLOW

ERROR ON A NONTERM

ERROR STATE STACK OVERFLOW

MARK MISSING FROM ERR MARK STACK

MARKSTACK OVERFLOW

REDUCE ON A NONTERM

SYMSTCK OVERFLOW–STACK PTR. number PUSHES–number MAX SIZE–number

SYMSTCK UNDERFLOW–STACK PTR–number PULLS–number

TOO MANY NAME TABLE ENTRIES–>100

TOO MANY NAMES IN STACK–>15

SIMULATION CONTROL ERRORS

The following errors are caused by user error and are ultimately fatal.

A CRAWL SPACE CANNOT HAVE A FLOOR OVER CRAWL SPACE

ADD SYSTEMS NOT ALLOWED TO NEW AHLDFL

User has specified ADD SYSTEMS in the RUN CONTROL block but has not attached the AHLDFL.

ADD ZONES NOT ALLOWED TO NEW BLDFL

User has specified ADD ZONES in the RUN CONTROL block but has not attached the BLDFL.

AN ATTIC CANNOT HAVE A CEILING UNDER ATTIC

BECAUSE OF PARSE ERRORS, NO SIMULATIONS WILL BE ATTEMPTED

Simulations are not allowed because a severe error has occured while parsing the users input deck.

BECAUSE OF SEVERE ERRORS, PROGRAM WILL BE STOPPED

A severe error has occured prior to this point in the processing. Simulations will not be allowed.

*****DATE & DAYS OUT OF RANGE ON file HEADER**
dd/mm/yyyy & num1 SHOULD BE IN RANGE dd/mm/yyyy THRU dd/mm/yyyy

The weather environment on the attached BLDFL or AHLDFL does not match the one on the attached WTHRFL.

EOF DETECTED ON WTHRFL AFTER num1 DAYS–SHOULD CONTAIN num2 DAYS UNEXPECTED END-OF-FILE ON WTHRFL

The WTHRFL actually contains fewer days than specified in its header.

INFORMATIVE MESSAGES

INPUT LATITUDE INVALID, SHOULD BE —> -90. <= num1 <= 90.

Latitude specified on LOCATION card is invalid.

INPUT LONGITUDE INVALID, SHOULD BE —> -180. <= num1 <= 180.

Longitude specified on LOCATION card is invalid.

INPUT TIME ZONE INVALID, SHOULD BE —> 0. <= num1 <= 24.

Time zone specified on LOCATION card is invalid.

*****LATITUDES DO NOT MATCH, BLDFL LAT = num1, AHLDFL LAT = num2**

The user has attached both the BLDFL and the AHLDFL The latitude of the location does not agree to within 1.E-5 on both files.

***LONGITUDES DO NOT MATCH, BLDFL LONG = num1 AHLDFL LONG = num2

The user has attached both the BLDFL and the AHLDFL. The longitude of the location does not agree to within 1.E-5 on both files.

MAXIMUM NUMBER OF SYSTEMS ON AHLDFL REACHED —> num1

User has exceeded the number of systems which can be on one AHLDFL.

NEW SYSTEMS NOT ALLOWED ON EXISTING AHLDFL

User has specified NEW SYSTEMS in the RUN CONTROL block and has attached an AHLDFL. User can only specify ADD SYSTEMS or REPLACE SYSTEMS if the AHLDFL is attached.

NEW ZONES NOT ALLOWED ON EXISTING BLDFL

User has specified NEW ZONES in the RUN CONTROL block and has attached a BLDFL. Only ADD ZONES or REPLACE ZONES can be specified when the BLDFL is attached.

NO ENVIRONMENTS SPECIFIED

The user has not attached the BLDFL or AHLDFL and has not specified any environments in his input.

NO LOCATION FOR SIMULATION

The user has not attached a WTHRFL and has not specified a location in the input deck.

NO SIMULATIONS ARE ALLOWED, PROGRAM WILL BE STOPPED

User has not specified that simulations are desired in the RUN CONTROL input block.

NO SIMULATIONS ARE REQUESTED, PROGRAM WILL BE STOPPED

User has not input any buildings, systems, or plants in the input deck.

***NONMATCH FOR file AGAINST WTHRFL
STATION num1 SHOULD BE num2 (WHTRFL)
YEAR num1 SHOULD BE num2 (WTHRFL)
TIME ZONE num1 SHOULD BE num2 (WTHRFL)

The weather environment on the attached BLDFL or AHLDFL does not match the one on the attached WTHRFL.

```
***NON MATCH OF ENVIRONMENT HEADERS—BLDFL VS. AHLDFL
TYPES = nbld nahl
NO. DAYS = nbld nahl
STATN = nbld nahl
YEAR = nbld nahl
FIRST DAY = nbld nahl
GROUND TEMPS =  mon1 n1bld n1alh mon2 n2bld n2ahl mon3 n3bld n3ahl
                mon4 n4bld n4ahl
                mon7
                mon10
EO TIME = nbld nahl
SIN DECL = nbld nahl
```

COS DECL = nbld nahl
TIME ZONE = nbld nahl
START DATE = daybld, monbld, yrbld . . . dayahl, monahl, yrahl

User has attached both the BLDFL and the AHLDFL. At least one of the above printer data does not match on both files. User has not created both files from the same environment data.

***NUMBER OF DAYS OUT OF RANGE ON file HEADER num1 DAYS SHOULD BE > 0 and <= num2

The weather environment on the attached BLDFL or AHLDFL does not match the one on the attached WTHRFL.

***NUMBER OF ENVIRONMENTS DO NOT MATCH

The user has attached both the BLDFL and the AHLDFL. The number of environments on each file does not agree.

ONLY ONE ATTIC FLOOR PER ATTIC

User has input more than one ATTIC FLOOR for the attic.

ONLY ONE CRAWL SPACE CEILING PER CRAWL SPACE

User has input more than one CRAWL SPACE CEILING for the crawl space.

PARITY ERROR ON WTHRFL

An error has occured while trying to read the WTHRFL.

PRECEDING SYSTEM NOT ON AHLDFL

User has tried to replace a system which does not exist on the attached AHLDFL.

PRECEDING SYSTEM NUMBER PREVIOUSLY INPUT

User has duplicated a system number used previously in the simulation.

PRECEDING ZONE NOT ON BLDFL

User has tried to replace a zone which does not exist on the attached BLDFL.

PRECEDING ZONE NUMBER PREVIOUSLY INPUT

User has duplicated a zone number used previously in the simulation.

REPLACE SYSTEMS MUST REPLACE AN EXISTING SYSTEM ON THE AHLDFL

User has tried to replace a system which does not exist on the attached AHLDFL.

REPLACE ZONES MUST REPLACE AN EXISTING ZONE ON THE BLDFL

User has tried to replace a zone which does not exist on the attached BLDFL.

REPLACE SYSTEMS NOT ALLOWED ON NEW AHLDFL

User has specified REPLACE SYSTEMS in the RUN CONTROL block but has not attached the AHLDFL.

REPLACE ZONES NOT ALLOWED ON NEW BLDFL

User has specified **REPLACE ZONES** in the **RUN CONTROL** block but has not attached the **BLDFL**.

SAME AS ZONE NOT YET DESCRIBED FOR THIS RUN

THE FOLLOWING SYSTEM IS NOT ON THE ATTACHED AHLDFL, SYSTEM num1

User has requested a system for the plant which does not exist on the attached **AHLDFL**.

THE FOLLOWING ZONE IS NOT ON THE ATTACHED BLDFL, ZONE num1

The user has request a zone on the fan system which does not exist on the attached **BLDFL**.

***** TIME ZONES DO NOT MATCH, BLDFL ZONE** = num1 **AHLDFL ZONE** = num2

The user has attached both the **BLDFL** and the **AHLDFL**. The time zone of the location does not agree to within 1.E-5 on both files.

TOO MANY DESIGN DAYS INPUT

The number of design day environments specified is greater than the maximum number allowed.

TOO MANY SIMULATIONS ATTEMPTED

The total number of buildings, zones, systems, and plants input by the user has exceeded the maximum number allowed.

*****USER INPUT NO. OF DAYS OUT OF RANGE, IS** num1 **SHOULD BE > 0 AND <=** num2

The number of days the user has requested for his weather environment is greater than the number of days on the attached **WTHRFL**.

*****USER INPUT NO. SKIP OUT OF RANGE, IS** num1 **SHOULD BE > = 0 AND <=** num2

The number of days the user wishes to skip before starting his weather environment is greater than the number of days on the attached **WTHRFL**.

USER INPUT START DATE dd/mm/yyyy **IS NOT IN WTHRFL RANGE OF** dd/mm/yyyy **THRU** dd/mm/yyyy

User has requested his weather environment to start on a date which is not on the attached **WTHRFL**.

USER INPUT END DATE dd/mm/yyyy **IS NOT IN WTHRFL RANGE OF** dd/mm/yyyy **THRU** dd/mm/yyyy

User has requested his/her weather environment to end on a date which is not on the attached **WTHRFL**.

*****WEATHER ENVIRONMENTS REQUESTED, BUT WTHRFL NOT ATTACHED**

User has requested a weather environment but has not attached a **WTHRFL**.

WEATHER TAPE <NDAYS=,SKIP> CLAUSE IGNORED

The user has input both forms of the weather tape card. The above one is ignored.

ZONE REQUIRES AN ATTIC–NOT PRESENT

This zone has a CEILING UNDER ATTIC but an attic has not yet been simulated.

ZONE REQUIRES A CRAWL SPACE–NOT PRESENT

This zone has a FLOOR OVER CRAWL SPACE but a crawl space has not yet been simulated.

PSYCHROMETRIC ERROR MESSAGES
(ALL ARE INFORMATIVE)

H OUT OF RANGE <SATUTH>

IF PSYWTR, MONTH= num DAY= num TDB= num TH= num PB= num RH= num W= num W<0 —> SET W=1.E-5

IN PSYDT, MONTH= num DAY= num TDB= num TWB= num PB= num W= num TDP= num TDP>TWB —> SET TDP=TWB

IN PSYRHT, MONTH= num DAY= num TDB= num TWB= num RH= num RH > 1 OR RH < 0 —> RH SET TO 0 OR 1

IN PSYTWD, MONTH= num DAY= num TDB= num W= num PB= num TDP= num TWB= num TWB DID NOT CONVERGE —> SET TWB=(TDB+TDP)/2

IN PSYVTW, MONTH= num DAY= num TDB= num W= num PB= num V= num V<0 —> SET V = 0.33

IN PSYWDP, MONTH= num DAY= num TDP= num PB= num W= num W<0 —> SET W = 1.E-5

IN PSYWTP, MONTH= mon DAY= mon TDB= num TWB= num PB= num TDB<TWB —> SET TWB = TDB

IN PSYWTH, MONTH= num DAY= num TDB= num H= num W= num W<0. —> SET W= 1.E-5

IN PSYWTP, MONTH= num DAY= num TDB= num TWB= num PB= num W= num W<0 —> SET W FOR A RH= .01

P OUT OF RANGE <SATUTP>

PSYCHROMETRIC ERROR SUMMARY

ROUTINE	NUMBER OF ERRORS
PSYDPT	num1
PSYRHT	num2
PSYTWD	num3
PSYVTW	num4
PSYWDP	num5
PSYWTH	num6
PSYWTP	num7
PSYWTR	num8

T OUT OF RANGE <SATUPT>

BUILDING LOADS ERRORS

BASE SURFACE DOES NOT SURROUND SUBSURFACE (CHKSBS)

Severe. A base surface/subsurface has been incorrectly described. The dump indicates the surface numbers. Reports 2, 9, 10, and 11 may be useful.

BACK SURFACES NOT IMPLEMENTED (SHDINT)

Severe. Program should not say this. Call program consultant. Effect of error unknown.

CTF CALCULATION DID NOT TERMINATE (RFCOMP)

Severe. The conduction transfer function terms did not converge to the required limits (.0001). The estimated and actual conductivities of the construct are given. This indicates the size of the error. If the error is not acceptable, a less massive construct must be used. Report 4 may be helpful.

CAPACITIES NOT ORDERED (CHKCS)

Severe, eventually fatal. In the temperature control ramp definition each capacity must be less than or equal to the preceeding one. Check the input and the dump. Report 2 may also be useful.

CAPACITIES OUT OF RANGE (CHKCS)

Severe, may be fatal. The first and last capacities on the control ramp must be 1, 0, or -1. No capacity may be greater than 1 or less than -1. Check the input and the dump. Report 2 may also be useful.

DETERMINANT = ZERO (INVERT)

Fatal. The surface vertices are probably wrong. Reports 9 and 11 may be helpful.

DIRECTION COSINE TOO LARGE (CTRAN)

Severe, then fatal. The surface vertices are probably out of order (should be counter-clockwise).

EXCEEDED MAX TEMPT RANGE (CALOAD)

Severe, then fatal. A zone temperature could not be computed. Check dumps.

EXCEEDED MIN TMP RANGE (CALOAD)

Severe, then fatal. A zone temperature could not be computed. Check dumps.

FATAL ERROR IN CALUTH (CALOAD)

Fatal. See previous error message and dumps.

FATAL ERROR IN CTRAN

Fatal. A result of one of the other tho CTRAN error messages. Automatic dump provid d. Reports 9 and 11 may be helpful.

FATAL ERROR IN INITGL

Fatal. The previous error message indicates the type of problem.

FATAL ERROR IN INITRF

Fatal. The previous message indicates the type of problem.

GENERAL SCHEDULE ELEMENT TOO LARGE (CHKGS)

Severe, No element in any schedule profile may be greater than 1. The Radiant, latent, etc., fractions may not be greater than 1 and may not sum to greater than 1. Check the input and the dump. Report 2 may also be useful.

GENERAL SCHEDULE ELEMENT TOO SMALL (CHKGS)

Severe. No element in any schedule profile may be less than 0. Check the input and dump. Report 2 may be useful.

INCORRECT GLASS TRANSMITTANCE (INITGL)

Severe, then fatal. The glass transmittance must be between 0.01 and 0.99. It is likely that a construct layer is not the one intended. The dump may identify it. Report 5 may also be needed.

INCORRECT INDEX OF REFRACTION (INITGL)

Severe, then fatal. The glass index of refraction must be between 1.01 and 2. It is likely that a construct layer is not the one intended. The dump may identify it. Report 5 may also be needed.

INCORRECT SHADE VALUES (INITGL)

Severe, then fatal. The interior shade properties must satisfy:

    0.0 <= TRANS <= 1.0
    0.0 <= REF <=1.0
    TRANS + REF <= 1.0

A construct layer may not be the one intended. The dump may identify it. Report 5 may also be needed.

INCORRECT SURFACE SHAPE NUMBER (SETUPV)

Fatal. Call program consultant. Reports 2, 9, 10, and 11 may be useful.

INSUFFICIENT DATA FOR RESPONSE FACTORS (INITRF)

Severe, then fatal. The dump should show to which construct this applies. Either the R-value or the quantity L+sert (D+CP/K) must be greater than 1E-6.

INTERIOR SHADE NOT INNER SURFACE (INITGL)

Severe, then fatal. The shade must be the innermost layer. There must be at least one glass in front of it. The dump may identify the construct causing the problem. Report 5 may also be needed.

INVALID DOT PRODUCT (CTRAN)

Severe, then fatal. The surface vertices are probably out of order.

RESPONSE FACTORS NOT COMPUTED (RESPNS)

Fatal. See program consultant.

SHADING COEFF NOT FIRST SURFACE (INITGL)

Severe, then fatal. A glass described by its shading coefficient must be the only layer in a window construct which uses it. The dump may identify the construct. Report 5 may also be needed.

SPACE TEMPERATURE OUT OF RANGE (CALOAD)

Severe, then fatal. The zone temperature has reached an impossible value. Check dumps.

SUNLIT AREA TOO LARGE (SHADOW)

Severe. A sunlit fraction > 1 has been computed and then reset to 1. The importance of this error depends on the surface and its relation to the total problem. For correction call consultant. Full error trace will use reports 9, 10, 17, 18, 19, and 20.

SUNLIT AREA TOO SMALL (SHADOW)

Severe. A negative sunlit area has been computed and then reset to 0. The importance of this error depends on the surface and its relation to the total problem. For correction call consultant. Full error trace will use reports 9, 10, 17, 18, and 20.

SUNLIT AREA TOO SMALL (SHDSBS)

Severe. A negative sunlit area has been computed and then reset to 0. The importance of this error depends on the surface and its relation to the total problem. For correction call consultant. Full error trace will use reports 9, 10, 17, 18, 19, and 20.

SUNLIT AREA TOO SMALL (SHDSBS)

Severe. A sunlit fraction > 1 has been computed and then reset to 1. The importance of this error depends on the surface and its relation to the total problem. For correction call consultant. Full error trace will use reports 9, 10, 17, 18, 19, and 20.

TEMPERATURES NOT ORDERED (CHKCS)

Severe, eventually fatal. In the temperature control ramp definition each temperature must be greater than or equal to the preceeding one. Check the input and the dump. Report 2 may also be useful.

TOO MANY CONSTRUCTS (INITRF)

Severe, then fatal. The building uses too many wall, window, etc., constructs. Reduce the number by using fewer constructs or doing a smaller number of zones.

TOO MANY FIGURES IN A SHADOW OVERLAP (OVRLAP)

Fatal. An overly complex shadowing combination has occurred. Reduce the number of shadowing surfaces.

TOO MANY FLUX FACTORS, ALL CONSTRUCTS (INITRF)

Severe, then fatal. The total number of flux conduction transfer terms has exceeded 80. See message TOO MANY RESPONSE FACTORS, ALL CONSTRUCTS.

TOO MANY GLASS PANES (INITGL)

Severe, then fatal. The maximum number of panes of glass in a window is 4. The dump may indicate which construct is causing the problem. Report 5 may also be needed.

TOO MANY HEAT TRANSFER SURFACES (BZSDAT)

Fatal. The total number of heat transfer surfaces in any one zone may not exceed 48. Check the input. Report 2 may be helpful.

TOO MANY ITERATIONS (CALOAD)

Severe, then fatal. A zone temperature could not be computed in the allowed number of iterations across the control ramp. Check dumps.

TOO MANY LAYERS IN CONSTRUCT (INITRF)

Severe, then fatal. The dump should show to which construct this applies. The maximum number of layers is 10.

TOO MANY RESPONSE FACTORS, ALL CONSTRUCTS (INITRF)

Severe, then fatal. The total number of temperature conduction transfer functions has exceeded 200. This is caused by too many massive surfaces. Reduce the number of different heavy constructs or do fewer zones in a single run. Report 3 will tell the number of factors for each construct.

TOO MANY SEARCH STEPS (FINDFD)

Fatal. The program could not determine the thickness of the reflective film on a pane of glass. Reports 2 and 5 may identify incorrect input. Look for unreasonable values of TRANS and FILM-TRANS.

TOO MANY SHADOW COMBINATIONS (SGCOMB)

Severe, then fatal. The zone has been described with too many surfaces which may shade each other. Simplify the zone and shadowing geometry.

TOO MANY SURFACES TOTAL (BZSDAT)

Severe, eventually fatal. The total number of surfaces describing the zone, including all shadowing surfaces and has exceeded 130. Reports 2, 10 may be helpful.

TOO MANY SURFACES WITH VARIABLE CONVECTION COEFFICIENTS (ISULHS)

Fatal. Only 10 surfaces may have tilts of less than 67.5 degrees or > 112.5 degrees. Check input. Reports 2 and 9 may be useful.

TOO MANY TEMPERATURE HISTORY TERMS (BZSDAT)

Severe, eventually fatal. The total number of temperature and flux history terms has exceeded about 800. Reduce the number of massive surfaces in the zone. Report 10 may be helpful.

TOO MANY VARIABLE CONVECTION SURFACES (BZSDAT)

Severe, eventually fatal. Only 10 surfaces may have tilts of less than 67.5 degrees or greater than 112.5 degrees. Check input. Report 2 may be helpful.

TOO MANY VERTICES IN A SHADOW OVERLAP (OVRLAP)

Fatal. An overly complex shadowing combination has occurred. Simplify the zone shadowing description.

TOO MANY WINDOW TYPES (INITGL)

Severe, then fatal. The building uses too many (>10) window constructs. Reduce the number by using fewer different types or fewer zones in a single run.

ZERO OR NEGATIVE SURFACE AREA (BZSDAT)

Severe, eventually fatal either the surface vertices are out of order (should be counter-clockwise) or the area of the subsurfaces is greater than the base surface area. Reports 9, 10, and 11 may be helpful.

SYSTEMS ERROR MESSAGES
(ALL FATAL)

CANT HAVE BUT ONE ZONE ON A DX PACKAGED UNIT SYSTEM

User has specified more than one zone on the DX PACKAGED UNIT SYSTEM. Only one zone is allowed.

CANT HAVE BUT ONE ZONE ON A SINGLE ZONE DRAW THRU SYSTEM

User has specified more than one zone on the single zone draw thru system. Only one zone is allowed.

REHEAT AND TSTAT BASEBOARD HEAT CANNOT BE IN SAME ZONE

User has input both a REHEAT CAPACITY and a BASEBOARD HEAT CAPACITY for the same zone.

THE SUPPLY AIR VOLUME RATE IS <= ZERO FOR ZONE num

User did not input a supply air volume flow rate for zone num which was > zero in the input deck.

TWOPIPE SIMULATION ERROR HEATING AND COOLING SUPPLIED TO COIL AT THE SAME TIME

User has scheduled both the heating and the cooling to be on at the same time. The input block EQUIPMENT SCHEDULES should be modified to prevent this.

FATAL ERRORS NOT CAUSED BY USER ERROR

BUFFER IN ERROR–EOF (INITZN)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–EDF (REPTZC)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–EOF (SIMZN)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–EOF (SUNCHK)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–PARITY (INITZN)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–PARITY (INITSG)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–PARITY (REPTZC)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–PARITY (SIMZN)

Fatal. A files handling problem. See program consultant.

BUFFER IN ERROR–PARITY (SUNCHK)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–EOF (INITBL)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–EOF (INITZN)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–EOF (INITSG)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–EOF (WRZNLC)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–PARITY (INITBL)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–PARITY (INITSG)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–PARITY (INITZM)

Fatal. A files handling problem. See program consultant.

BUFFER OUT ERROR–PARITY (WRZNLC)

A files handling problem. See program consultant.

DDYHLR CALLED W/O CALLING ENV. HDR. FIRST

ERROR IN READING ENV DAILY RECORD IN SIMTEP

ERROR IN READING ENV HEADER IN SIMSYS

ERROR IN READING ENV RECORD IN SIMTEP

ERROR IN READING SYS RECORD IN SIMTEP

ERROR IN READING ZONE LOADS

FH FAILED

FAILED

INVALID COMMAND PASSED TO FHSUP

ILLEGAL CALL TO MIXAIR

IN MIXAIR, AHTYPE OUT OF RANGE

INVALID PARAMETERS PASSED TO DDY HANDLER
IOCMND = num1 FILTYP = num2 RECTYP = num3 FHENV = num4
FHDAY = num5 SHOULD BE > 0 AND <= num6 BUFILL = num7

INVALID PARAMETERS PASSED TO ENV. HDR. HANDLER
IOCMND = num1 FILTYP = num2 RECTYP = num3 FHENV = num4
FHDAY = num5 SHOULD BE > 0 AND <= num6 BUFILL = num7

INVALID PARAMETERS PASSED TO WTH HANDLER
IOCMND = num1 FILTYP = num2 RECTYP = num3 FHENV = num4
FHDAY = num5 SHOULD BE > 0 AND <= num6 BUFILL = num7

INVALID PARAMETERS PASSED SYSHLR
IOCMND = num1 RECTYP = num2 RECNO = num3 FHENV = num4
CENVNO = num5 FHDAY = num6 SHOULD BE > 0 AND <= num7

INVALID PARAMETERS PASSED TO ZONHLR
IOCMND = num1 RECTYP = num2 RECNO = num3 FHENV = num4
CENVNO = num5 FHDAY = num6 SHOULD BE > 0 AND <= num7

MISMATCH IN LOAD COMPONENTS REPORT (REPTZC)

Severe. Call program consultant.

READ ATTIC TEMPS FAILED (PCTCHK)

Fatal. A files handling problem. See program consultant.

READ CRAWL SPACE TEMPS FAILED (PCTCHK)

Fatal. A files handling problem. See program consultant.

READ ENVIRONMENT DATA FAILED (SIMZN)

Fatal. A files handling problem. See program consultant.

READ ENVIRONMENT HEADER FAILED (INITSG) Fatal.
BUFFER IN ERROR–EOF (INITSG)

Fatal. A files handling problem. See program consultant.

READ ENVIRONMENT HEADER FAILED (SIMZN)

Fatal. A files handling problem. See program consultant.

SIMULATION RECORD IS NOT DESIGN DAY

SYSTEMS WRITE FAILED IN GENTEPS

WRITE ATTIC TEMPS FAILED (WRLDFL)

Fatal. A files handling problem. See program consultant.

WRITE CRAWL SPACE TEMPS FAILED (WRLDFL)

Fatal. A files handling problem. See program consultant.

WRITE ZONE HEADER FAILED (SIMZN)

Fatal. A files handling problem. See program consultant.

WRITE ZONE LOADS FAILED (WRLDFL)

Fatal. A files handling problem. See program consultant.

SUBJECT INDEX

BLAST COMMAND INDEX

Page numbers refer to the major section in the Users Manual where the Command is discussed.

Page	Command	*Defaults*
25	BEGIN INPUT;	
26	RUN CONTROL:	
26	NEW ADD REPLACE ZONES,	
27	NEW ADD REPLACE AIR SYSTEMS,	
27	CENTRAL PLANT,	
27	PRINT LIBRARY,	no printout
27	UNIT (IN=usname, OUT=usname), ENGLISH or METRIC, ENGLISH or METRIC or UNITS (usname),	(IN=ENGLISH, OUT=ENGLISH)
27, 27	REPORTS (usname, usname, . . .); (and/or) WALLS ZONE SHADE CONTINUOUS COIL LOADS SYSTEM EQUIPMENT PARAMETERS	
33	DEFINE REDEFINE TEMPORARY DELETE LOCATION: usname=(LAT=usn1, LONG=usn2, TZ=usn3); . . . END;	
33-35	DEFINE REDEFINE TEMPORARY DELETE DESIGN DAYS: usname=(HIGH=usn1, LOW=usn2, WB=usn3, DATE=usdate, PRES=usn4, WS=usn5, DIR=usn6, CLEARNESS=usn7, usname1, usname2); . . . END;	usn1=95, usn2=52, usn3=78, usdate=21 JUL, usn4=405, usn5=7.5, usn6=270, usn7=1.0, usname1=WEEKDAY, usname2=blank

```
Page                                                          Defaults
30-33     DEFINE      }
          REDEFINE    } MATERIALS:
          TEMPORARY   }
          DELETE      } usname=(L=usn1, K=usn2, CP=usn3,
                              D=usn4, ABS=usn5,
                              TABS=usn6, R=usn7,
                              TRANS=usn8, IR=usn9,
                              FILMTRANS=usn10,
                              REF=usn11, usname1, usname2);
                        .
                        .
                        .
          END;

30        DEFINE      }
          REDEFINE    } surface type:
          TEMPORARY   }       { WALLS
          DELETE      }       { ROOFS
                         (or) { FLOORS
                              { WINDOWS
                              { DOORS
                        usname=(material1, material2, . . . ),
                        .
                        .       others of same surface-type
                        .
          END;
          .
          .     next surface-type
          .

36-37     DEFINE      }
          REDEFINE    } SCHEDULE (usname):
          TEMPORARY   }
          DELETE      }
                        day THRU day=(hour TO hour-usn,
                                      hour TO hour-usn, . . . );

                            (or)=(usn1, usn2, . . . usn24),
                            (or)=(usn, hour TO hour-usn, usn, . . . ),
                      { SUNDAY=
                      { MONDAY=
                      { TUESDAY=
                 (or) { WEDNESDAY=
                      { THURSDAY=
                      { FRIDAY=
                      { SATURDAY=
                      { HOLIDAY=
                 (and/or) day=day,
                 (and) HOLIDAY=day,
          END;
```

```
Page                                                                      Defaults
37-39      DEFINE     ⎫
           REDEFINE   ⎬ CONTROLS (usname):
           TEMPORARY  ⎪
           DELETE     ⎭

              PROFILES:
                  usname=(usn1 AT usn2, usn3 AT usn4, . . . ),
                  .
                  .
              SCHEDULES:
                  day THRU day=(hour TO hour-usname . . . ),
                  .
                  .
                  HEATING ON FROM usdate THRU usdate,                     01 JAN THRU 31 DEC
                  COOLING ON FROM usdate THRU usdate,                     01 JAN THRU 31 DEC
           END;

40         PROJECT="usname";
40         LOCATION=usname;

40         DESIGN DAYS=usname, usname, . . . , usname;
40, 41     WEATHER TAPE FROM usdate THRU usdate;
41         GROUND TEMPERATURES=(usn1, usn2, . . . , usn12);               (55, 55, 55, 55, 55, 55,
                                                                           55, 55, 55, 55, 55, 55)
47   BEGIN BUILDING DESCRIPTION; BUILDING="usname";
48         DIMENSION: usname1=usn1, usname2=usn2, . . . ;                  - - -
49         NORTH AXIS=usn;                                                0

71-73      DETACHED SHADING "usname": (usn1 BY usn2)
                                    or ( ( usn1, usn1'),
                                       (usn2, usn2'), . . . )
              STARTING AT (usn, usn, usn)
              FACING (usn)
              TILTED (usn);

49         ZONE usn "usname":
50, 51        DIMENSION: usname1=usn1, usname2=usn2, . . . ;
50, 51        ORIGIN: (usn, usn, usn);                                    (0, 0, 0)
50, 51        NORTH AXIS=usn;
51-60         surface type:
                 STARTING AT (usn, usn, usn)
                 FACING (usn)
                 TILTED (usn)
                 surface-name (usn1 BY usn2)
                      or ( (usn1, usn1'), (usn2, usn2'), . . . )
                    OTHER SIDE COEFFICIENTS (usn1, usn2, usn3,
                                            usn4, usn5, usn6,
                                            usn7)
                    WITH subsurface-type OF TYPE subsurface-name
                                            (usn1 BY usn2)
                          REVEAL (usn)
                       AT (usn1, usn2)
                          AND (usn1, usn2)
                          .
                          .
                          .
```

Page		Defaults
	WITH subsurface-type OF TYPE subsurface-name (usn1 BY usn2)	
	.	
	.	
	.	
	STARTING AT (usn, usn, usn)	
	.	
	.	
	.	
	surface-type:	
	.	
	.	
	.	
60	PEOPLE=usn1, schedule-name, AT ACTIVITY LEVEL usn2, usn3 PERCENT RADIANT;	usn1=0, usn2=.45, usn3=70
60, 61	LIGHTS=usn1, schedule-name, usn2 PERCENT RADIANT, usn3 PERCENT RETURN AIR, usn4 PERCENT LOST;	usn1=0, usn2=50, usn3=0, usn4=0
60, 61	ELECTRIC EQUIPMENT=usn1, schedule-name, usn2 PERCENT RADIANT, usn3 PERCENT LATENT, is usn4 PERCENT LOST;	usn1=0, usn2=30, usn3=0, usn4=0
60, 61	GAS EQUIPMENT=usn1, schedule-name, usn2 PERCENT RADIANT, usn3 PERCENT LATENT, usn4 PERCENT LOST;	usn1=0, usn2=30, usn3=0, usn4=0
	INFILTRATION=usn1, schedule-name, WITH COEFFICIENTS, (usn2, usn3, usn4, usn5);	usn1=0, (.606, .0202, .00598, 0)
62	CONTROLS=control-schedule-name, usn1 HEATING, usn2 COOLING;	usn1=3.4×10^9 usn2=3.4×10^9
61	BASEBOARD HEATING=(usn1 AT usn2, usn3 AT usn4), usn5 PERCENT RADIANT;	
	END ZONE;	
	.	
	. other zones	
	.	
	END BUILDING DESCRIPTION;	
83	BEGIN FAN SYSTEM DESCRIPTION;	
84, 188-190	system type SYSTEM usn "usname" SERVING ZONES usn, usn, . . . ;	
	MULTIZONE	
	TERMINAL REHEAT	
	VARIABLE VOLUME	
	UNIT VENTILATOR	
	THREE DECK MULTIZONE	

```
Page                                                                     Defaults
          (or) TWO PIPE FAN COIL
               FOUR PIPE FAN COIL
               DUAL DUCT VARIABLE VOLUME
               SINGLE ZONE DRAW THRU
               SUBZONE REHEAT
               DX PACKAGES UNIT

85, 86            FOR ZONE usn:
                     SUPPLY AIR VOLUME=usn;                              Required input
                     MINIMUM AIR FRACTION=usn;                               0.1
                     EXHAUST AIR VOLUME=usn;                                 0
                     REHEAT CAPACITY=usn;                                    0
                     REHEAT ENERGY SUPPLY=HOT WATER;                     HOT WATER
                                  (or) =STEAM;
                                  (or) =GAS;
                                  (or) =ELECTRIC;                            1
                     BASEBOARD HEAT CAPACITY=usn;                            0.0
                     BASEBOARD HEAT ENERGY SUPPLY=HOT WATER;
                                        (or) =STEAM;
                                        (or) =GAS;
                                        (or) =ELECTRIC;
                     ZONE MULTIPLIER=usn;
                  END ZONE;

86-90     OTHER SYSTEM PARAMETERS:
               SUPPLY FAN PRESSURE=usn;                                  2.5
               EXHAUST FAN PRESSURE=usn;                                 1
               RETURN FAN PRESSURE=usn;                                  0
               SUPPLY FAN EFFICIENCY=usn;                                0.7
               EXHAUST FAN EFFICIENCY=usn;                               0.7
               RETURN FAN EFFICIENCY=usn;                                0.7
               COLD DECK CONTROL=FIXED SET POINT;                        FIXED SET POINT
                          (or) =OUTSIDE AIR CONTROLLED:
                          (or) =ZONE CONTROLLED;
               COLD DECK TEMPERATURE=usn;                                55
               COLD DECK THROTTLING RANGE=usn;                           7.2
               COLD DECK CONTROL SCHEDULE=(usn AT usn,
                                      usn AT usn);                       See page 87
               HEATING COIL CAPACITY=usn;                                3412000
               HEATING COIL ENERGY SUPPLY=HOT WATER                      HOT WATER
                               (or) =GAS
                               (or) =ELECTRIC
                               (or) =STEAM
               HOT DECK CONTROL=FIXED SET POINT;                         FIXED SET POINT
                          (or)=OUTSIDE AIR CONTROLLED;
                          (or)=ZONE CONTROLLED;
               HOT DECK TEMPERATURE-usn;                                 140
               HOT DECK THROTTLING RANGE=usn;                            72
               HOT DECK CONTROL SCHEDULE=(usn AT usn,                    87
                                     usn AT usn);
               MIXED AIR CONTROL=FIXED PERCENT;                          FIXED PERCENT
                          (or) =FIXED AMOUNT;
                          (or) =TEMPERATURE ECONOMY CYCLE;
```

Page		*Defaults*
	(or) =RETURN AIR ECONOMY CYCLE;	
	(or) =ENTHALPY ECONOMY CYCLE;	
	DESIRED MIXED AIR TEMPERATURE=usn;	COLD DECK TEMPERATURE
	(or)=COLD DECK TEMPERATURE;	
	OUTSIDE AIR VOLUME=usn;	0
	WEEKDAY MINIMUM OUTSIDE AIR SCHEDULE= (usn TO usn-usn);	See page 88
	WEEKEND MINIMUM OUTSIDE AIR SCHEDULE= (usn TO usn-usn);	See page 88
	WEEKDAY MAXIMUM OUTSIDE AIR SCHEDULE= (usn TO usn-usn);	(00 to 24-1)
	WEEKEND MAXIMUM OUTSIDE AIR SCHEDULE= (usn TO usn-usn);	(00 TO 24-1)
	PREHEAT COIL LOCATION=NONE;	NONE
	(or) =OUTSIDE AIR DUCT;	
	(or)=MIXED AIR DUCT;	
	PREHEAT TEMPERATURE=usn;	46.4
	PREHEAT COIL CAPACITY=usn;	0
	PREHEAT ENERGY SUPPLY=HOT WATER;	HOT WATER
	(or)=GAS;	
	(or)=ELECTRIC;	
	(or)=STEAM;	
	GAS BURNER EFFICIENCY=usn;	0.8
	VAV MINIMUM AIR FRACTION=usn;	0.1
	VAV VOLUME CONTROL TYPE=INLET VANES;	INLET VANES
	(or)=VARIABLE FAN SPEED;	
	(or)=DISCHARGE DAMPERS;	
	FAN POWER COEFFICIENTS=(usn, usn, usn, usn, usn);	(0, 0, 0, 0, 0)
	HUMIDIFIER TYPE=NONE;	NONE
	(or)=STEAM;	
	(or)=HOT WATER;	
	(or)=ELECTRIC;	
	HUMIDISTAT LOCATION=usn;	– – –
	HUMIDISTAT SET POINT=usn;	50
	END OTHER SYSTEM PARAMETERS;	
90-93	COOLING COIL DESIGN PARAMETERS;	
	COIL TYPE=CHILLED WATER;	CHILLED WATER
	(or) =DIRECT EXPANSION;	
	(or) =DX;	

Page		*Defaults*
	ENTERING REFRIGERANT TEMPERATURE=usn;	See following COOLING COIL TYPES for defaults
	LEAVING REFRIGERANT TEMPERATURE=usn;	
	TOTAL COOLING LOAD=usn;	
	NUMBER OF TUBE CIRCUITS=usn;	
	ENTERING WATER TEMPERATURE=usn;	
	ENTERING AIR DRY BULB TEMPERATURE=usn;	
	ENTERING AIR WET BULB TEMPERATURE=usn;	
	LEAVING WATER TEMPERATURE=usn;	
	LEAVING AIR DRY BULB TEMPERATURE=usn;	
	LEAVING AIR WET BULB TEMPERATURE=usn;	
	WATER VELOCITY=usn;	
	WATER VOLUME FLOW RATE=usn;	
	AIR FACE VELOCITY=usn;	
	AIR VOLUME FLOW RATE=usn;	
	BAROMETRIC PRESSURE=usn;	
	END COOLING COIL DESIGN PARAMETERS;	

For DX Packages Coils

90-93	COOLING COIL DESIGN PARAMETERS;	
	DXCOIL1 (usn, usn, usn);	(4589.14, 1.63, -.02011);
	DXCOIL2 (usn, usn, usn);	(-25.342, .02492, .000461);
	DXCOIL3 (usn, usn, usn);	(.01715, -.000051, -1.715E-8);
	END COOLING COIL DESIGN PARAMETERS;	

For Direct Expansion Coils

90-93	COOLING COIL DESIGN PARAMETERS;	– – –
	COIL TYPE=DX;	
	(or)=DIRECT EXPANSION;	
	AIR VOLUME FLOW RATE=usn;	12000
	BAROMETRIC PRESSURE=usn;	405
	AIR FACE VELOCITY=usn;	600
	ENTERING AIR DRY BULB TEMPERATURE=usn;	80
	ENTERING AIR WET BULB TEMPERATURE=usn;	67
	LEAVING AIR DRY BULB TEMPERATURE=usn;	55
	LEAVING AIR WET BULB TEMPERATURE=usn;	44
	ENTERING REFRIGERANT TEMPERATURE=usn;	40
	LEAVING REFRIGERANT TEMPERATURE=usn;	40
	TOTAL COOLING LOAD=usn;	487.38
	NUMBER OF TUBE CIRCUITS=usn;	20
	END COOLING COIL DESIGN PARAMETERS;	

For Water Coils in Fan Coil Units

90-93	COOLING COIL DESIGN PARAMETERS;	
	AIR VOLUME FLOW RATE=usn;	600
	BAROMETRIC PRESSURE=usn;	406.8
	ENTERING AIR DRY BULB TEMPERATURE=usn;	80
	ENTERING AIR WET BULB TEMPERATURE=usn;	67
	LEAVING AIR DRY BULB TEMPERATURE=usn;	60.4
	ENTERING WATER TEMPERATURE=usn;	45
	LEAVING WATER TEMPERATURE=usn;	54.6
	WATER VOLUME FLOW RATE=usn;	4
	END COOLING COIL DESIGN PARAMETERS;	

Page		*Defaults*
For All Other Chilled Water Coils		
90-93	COOLING COIL DESIGN PARAMETERS;	
	COIL TYPE=CHILLED WATER;	– – –
	AIR VOLUME FLOW RATE=usn;	– – –
	BAROMETRIC PRESSURE=usn;	405
	AIR FACE VELOCITY=usn;	490
	ENTERING AIR DRY BULB TEMPERATURE=usn;	85
	ENTERING AIR WET BULB TEMPERATURE=usn;	64
	LEAVING AIR DRY BULB TEMPERATURE=usn;	55
	LEAVING AIR WET BULB TEMPERATURE=usn;	52.7
	ENTERING WATER TEMPERATURE=usn;	45
	LEAVING WATER TEMPERATURE=usn;	55
	WATER VOLUME FLOW RATE=usn;	– – –
	WATER VELOCITY=usn;	275
	END COOLING COIL DESIGN PARAMETERS;	
93	HEAT RECOVERY PARAMETERS:	
	HTREC1 (usn, usn, usn);	(.85, 0, 0)
	HTREC2 (usn, usn, usn);	(0, 0, 0)
	HTREC3 (usn, usn, usn);	(0, 0, 0)
	HTPWR (usn, usn, usn);	(0, 0, 0)
	HEAT RECOVERY CAPACITY=usn;	341200000
	END HEAT RECOVERY PARAMETERS;	
95, 179-187	DX CONDENSING UNIT PARAMETERS:	
	RCAVCD (usn, usn, usn);	(.0080, -.007067, .0000185)
	RPWRCD (usn, usn, usn);	(.1456, .9554, -.16476)
	ADJECD (usn, usn, usn);	(.2984, .1334, 34.603)
	DESIGN SATURATED SUCTION TEMPERATURE=usn;	40
	DESIGN SATURATED CONDENSING TEMP=usn;	122
	MINIMUM SATURATED CONDENSING TEMP=usn;	88
	UNLOADER THROTTLING RANGE=usn;	4
	CONDENSER UA=usn;	27.43
	SCT TEMPERATURE RISE=usn	2.63
	DESIGN FULL LOAD POWER RATIO=usn;	3.26
	DX CONDENSING UNIT CAPACITY=usn;	487.3
	END DX CONDENSING UNIT PARAMETERS;	
94-95	EQUIPMENT SCHEDULES:	
	SYSTEM OPERATION=CONTINUOUS (or) =INTERMITTENT	CONTINUOUS
	WEEKDAY SYSTEM SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .);	(08 TO 18-ON, 18 TO 08-OFF)
	WEEKEND SYSTEM SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .);	(00 TO 24-ON)
	WEEKDAY PREHEAT SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .);	(00 TO 24-ON)
	WEEKEND PREHEAT SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .),	(00 TO 24-ON)
	WEEKDAY HEATING SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .);	(00 TO 24-ON)
	WEEKEND HEATING SCHEDULE= (usn TO usn-usn, usn TO usn-usn, . . .);	(00 TO 24-ON)

```
Page                                                                  Defaults
                 WEEKDAY COOLING SCHEDULE=
                    (usn TO usn-usn, usn TO usn-usn, . . . );         (00 TO 24-ON)
                 WEEKEND COOLING SCHEDULE=
                    (usn TO usn-usn, usn TO usn-usn, . . . );         (00 TO 24-ON)
                 WEEKDAY HEAT RECOVERY SCHEDULE=
                    (usn TO usn-usn, usn TO usn-usn, . . . );         (00 TO 24-ON)
                 WEEKEND HEAT RECOVERY SCHEDULE-
                    (usn TO usn-usn, usn TO usn-usn, . . . );         (00 TO 24-ON)
                 PREHEAT CAPACITY ON FROM usdate THRU usdate;         01 JAN THRU 31 DEC
                 HEATING CAPACITY ON FROM usdate THRU usdate;         01 JAN THRU 31 DEC
                 COOLING CAPACITY ON FROM usdate THRU usdate;         01 JAN THRU 31 DEC
                 HEAT RECOVERY ON FROM usdate THRU usdate;            00 JAN THRU 00 JAN (ie off)
             END EQUIPMENT SCHEDULES;
          END SYSTEM;
END FAN SYSTEM DESCRIPTION;

107 BEGIN CENTRAL PLANT DESCRIPTION;
             PLANT usn "usname" SERVING SYSTEMS usn1, usn2, . . .;
107    or    PLANT usn "usname" SERVING ALL SYSTEMS;
109-112          EQUIPMENT SELECTION:
                 usn equipment-type OF SIZE usn (usn AVAILABLE);      (ALL AVAILABLE)
                    BOILER
                    CERAMIC COOLING TOWER
                    CHILLER
                    COLD STORAGE TANK
                    COOLING TOWER
                    DIESEL GENERATOR
                    DOUBLE BUNDLE CHILLER
                    GAS TURBINE
             (and/or)   HEAT PUMP
                    HOT STORAGE TANK
                    ONE-STAGE ABSORBER
                    OPEN CHILLER
                    RECIPROCATING CHILLER
                    SOLAR COLLECTORS
                    STEAM TURBINE
                    TWO-STAGE ABSORBER
                    TWO-STAGE ABSORBER W/ECON
               .
               .
               .
                 END EQUIPMENT SELECTION;

112, 113         EQUIPMENT ASSIGNMENT:                                If not specified,
                 equipment-type:                                      defaults to allocation
                    FOR L=usn USE (usn, usn);                         strategy of App. G.
                    .
                    .
                    .
                 .
                 .
                 .
                 END EQUIPMENT ASSIGNMENT;
```

Page		*Defaults*
113, 114	PART LOAD RATIOS: Equipment-type (MIN=usn, MAX=usn, BEST=usn, ELECTRICAL=usn); . . . END PART LOAD RATIOS;	Defaults for each equipment-type are given on page 114.
114, 115	SCHEDULE: WEEKDAY HOT WATER= (usn TO usn-usn, usn TO usn-usn, . . .); WEEKEND HOT WATER= (usn TO usn-usn, usn TO usn-usn, . . .); END SCHEDULE;	 (00 TO 24-0) (00 TO 24-0)
115-120	SPECIAL PARAMETERS: parameter-name=usn; . . . END SPECIAL PARAMETERS;	Defaults are given in the Special Parameters Table, page 117.
120, 121 App G	EQUIPMENT PERFORMANCE PARAMETERS: parameter-name (usn, usn, usn); . . . END EQUIPMENT PERFORMANCE PARAMETERS;	Defaults are given in the equipment Performance Coefficients Table, page 194.
121, 122	FOR SYSTEM usn: SYSTEM MULTIPLIER=usn; END FOR SYSTEM;	 1
122	LIFE CYCLE COST PARAMETERS: INTEREST RATE=usn; LABOR INFLATION=usn; SUPPLIES INFLATION=usn; PROJECT LIFE=usn; UNIT LABOR COST=usn; ADJUSTMENT FACTOR=usn; PAYMENT TIME=usn; END LIFE CYCLE COST PARAMETERS;	 10. percent 0. percent 0. percent 25 years 20 dollar/hour 1.0 0.5

Page		*Defaults*
122-125	ENERGY COST: ELECTRICITY: DIESEL FUEL: (or) GAS TURBINE FUEL: BOILER FUEL: ENERGY UNIT=usn, UNIT COST=usn, COST ESCALATION FACTOR=usn, MINIMUM MONTHLY CHARGE=usn, MINIMUM PEAK LOAD=usn, DEMAND CHARGE=usn, INFLATION=usn; END ENERGY COST;	Defaults for each energy type are given on page 125
125-127	REFERENCE EQUIPMENT COST: equipment type: SIZE=usn, INSTALLATION COST FACTOR=usn, COST=usn, MAJOR OVERHAUL COST=usn, MINOR OVERHAUL COST=usn, CONSUMABLES=usn, MAINTENANCE=usn, HOURS TO MAJOR OVERHAUL=usn, HOURS TO MINOR OVERHAUL=usn, LIFE=usn; . . . END REFERENCE EQUIPMENT COST;	Defaults are given in Reference Equipment Cost Table–page 127
126, 127	ACTUAL EQUIPMENT COST: equipment-type: SIZE=usn, INSTALLATION COST FACTOR=usn, COST=usn MAJOR OVERHAUL COST=usn, MINOR OVERHAUL COST=usn, CONSUMABLES=usn, MAINTENANCE=usn, HOURS TO MAJOR OVERHAUL=usn, HOURS TO MINOR OVERHAUL=usn, LIFE=usn; . . . END ACTUAL EQUIPMENT COST;	If omitted for type and size, defaults are Reference Equipment Costs

Page		*Defaults*
128	OTHER COST PARAMETERS:	
	BUILDING CAPITAL COST=usn;	0 dollars
	ANNUAL BUILDING MAINTENANCE=usn;	0 dollars
	PERIODIC BUILDING COSTS=usn, PERIOD=usn;	0 dollars, 0 years
	FAN SYSTEM CAPITAL COST=usn;	0 dollars
	ANNUAL FAN SYSTEM MAINTENANCE=usn;	0 dollars
	PERIODIC FAN SYSTEM COSTS=usn, PERIOD=usn;	0 dollars, 0 years
	END PLANT;	

```
        .
        .
        .
    END CENTRAL PLANT DESCRIPTION;
END INPUT;
```

Hittle, Douglas C
The Building Loads Analysis System Thermodynamics (BLAST) program, version 2.0 : users manual. -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from National Technical Information Service, 1979.
275 p ; 27 cm. (Technical report ; E-153)
Contents. v. 1, BLAST user instructions. v. 2, BLAST program library and example.

1. BLAST (computer program). 2. Buildings-energy consumption. I. Series: U.S. Army Construction Engineering Research Laboratory. Technical report ; E-153.

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